NUREG/CR-5250
UCID-21517
Vol. 4

Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains

Results and Discussion for the Batch 3 Sites

Prepared by D. L. Bernreuter, J. B. Savy, R. W. Mensing, J. C. Chen

Lawrence Livermore National Laboratory

Prepared for
U.S. Nuclear Regulatory
Commission

NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 1717 H Street, N.W.
   Washington, DC 20555
2. The Superintendent of Documents, U.S. Government Printing Office, Post Office Box 37082,
   Washington, DC 20013-7082
3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices; Licensee Event Reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, and NRC booklets and brochures. Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations,* and *Nuclear Regulatory Commission Issuances.*

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal and periodical articles, and transactions. *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Division of Information Support Services, Distribution Section, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

NUREG/CR-5250
UCID-21517
Vol. 4

Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains

Results and Discussion for the Batch 3 Sites

Manuscript Completed: November 1988
Date Published: January 1989

Prepared by
D. L. Bernreuter, J. B. Savy, R. W. Mensing, J. C. Chen

Lawrence Livermore National Laboratory
7000 East Avenue
Livermore, CA 94550

Prepared for
Division of Engineering and System Technology
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN A0448

Abstract

The EUS Seismic Hazard Characterization Project (SHC) is the outgrowth of an earlier study performed as part of the U.S. Nuclear Regulatory Commission's (NRC) Systematic Evaluation Program (SEP). The objectives of the SHC were: (1) to develop a seismic hazard characterization methodology for the region east of the Rocky Mountains (EUS), and (2) the application of the methodology to 69 site locations, some of them with several local soil conditions. The method developed uses expert opinions to obtain the input to the analyses. An important aspect of the elicitation of the expert opinion process was the holding of two feedback meetings with all the experts in order to finalize the methodology and the input data bases. The hazard estimates are reported in terms of peak ground acceleration (PGA) and 5% damping velocity response spectra (PSV).

A total of eight volumes make up this report which contains a thorough description of the methodology, the expert opinion's elicitation process, the input data base as well as a discussion, comparison and summary volume (Volume VI).

Consistent with previous analyses, this study finds that there are large uncertainties associated with the estimates of seismic hazard in the EUS, and it identifies the ground motion modeling as the prime contributor to those uncertainties.

The data bases and software are made available to the NRC and to public uses through the National Energy Software Center (Argonne, Illinois).

Table of Contents
Volume IV

List of Tables and Figures

The same format for the tables and figures are used for every site. The following is an exhaustive list of all tables and figures presented in this volume.

The symbol "SN" in the following refers to "Site Number" and the corresponding page numbers are given in the table on page x.

List of Additional Tables and Figures

PAGE REFERENCE OF TABLES AND FIGURES

Site SN	Table Number	Figure Number												
	2.SN.1	2.SN.1	2.SN.2	2.SN.3	2.SN.4	2.SN.5	2.SN.6	2.SN.7	2.SN.8	2.SN.9	2.SN.10	2.SN.11	2.SN.12	2.SN.13
1. Beaver Valley	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2. Big Rock Point	28	29	30	31	32	33	34	35	36	37	38			
3. Braidwood	41	42	43	44	45	46	47	48	49	50	51	52	53	54
4. Byron	56	57	58	59	60	61	62	63	64	65	66			
5. Clinton	69	70	71	72	73	74	75	76	77	78	79	80	81	82
6. Cook	84	85	86	87	88	89	90	91	92	93	94	95		
7. Davis Besse	97	98	99	100	101	102	103	104	105	106	107	108		
8. Dresden	110	111	112	113	114	115	116	117	118	119	120			
9. Fermi	122	123	124	125	126	127	128	129	130	131	132			
10. Kawaunee	134	135	136	137	138	139	140	141	142	143	144	145	146	
11. LaSalle	148	149	150	151	152	153	154	155	156	157	158			
12. Palisades	160	161	162	163	164	165	166	167	168	169	170			
13. Perry	172	173	174	175	176	177	178	179	180	181	182			
14. Point Beach	184	185	186	187	188	189	190	191	192	193	194			
15. Quad Cities	196	197	198	199	200	201	202	203	204	205	206			
16. Zion	208	209	210	211	212	213	214	215	216	217	218			

Foreword

The impetus for this study came from two unrelated needs of the Nuclear Regulatory Commission (NRC). One stimulus arose from the NRC funded "Seismic Safety Margins Research Programs" (SSMRP). The SSMRP's task of simplified methods needed to have available data and analysis software necessary to compute the seismic hazard at any site located east of the Rocky Mountains which we refer to as the Eastern United States (EUS) in a form suitable for use in probabilistic risk assessment (PRA). The second stimulus was the result of the NRC's discussions with the U.S. Geological Survey (USGS) regarding the USGS's proposed clarification of their past position with respect to the 1886 Charleston earthquake. The USGS clarification was finally issued on November 18, 1982, in a letter to the NRC, which states that:

> "Because the geologic and tectonic features of the Charleston region are similar to those in other regions of the eastern seaboard, we conclude that although there is no recent or historical evidence that other regions have experienced strong earthquakes, the historical record is not, of itself, sufficient ground for ruling out the occurrence in these other regions of strong seismic ground motions similar to those experienced near Charleston in 1886. Although the probability of strong ground motion due to an earthquake in any given year at a particular location in the eastern seaboard may be very low, deterministic and probabilistic evaluations of the seismic hazard should be made for individual sites in the eastern seaboard to establish the seismic engineering parameters for critical facilities."

Anticipation of this letter led the Office of Nuclear Reactor Regulation to jointly fund a project with the Office of Nuclear Regulatory Research. The results were presented in Bernreuter et. al., (1985), and the objectives were:

1. to develop a seismic hazard characterization methodology for the entire region of the United States east of the Rocky Mountains.
2. to apply the methodology to selected sites to assist the NRC staff in their assessment of the implications in the clarification of the USGS position on the Charleston earthquake, and the implications of the occurrence of the recent earthquakes such as that which occurred in New Brunswick, Canada, in 1982.

The methodology used in that 1985 study evolved from two earlier studies that the Lawrence Livermore National Laboratory (LLNL) performed for the NRC. One study, Bernreuter and Minichino (1983), was part of the NRC's Systematic Evaluation Program (SEP) and is simply referred hereafter to as the SEP study. The other study was part of the SSMRP.

At the time (1980-1985), an improved hazard analysis methodology and EUS seismicity and ground motion data set were required for several reasons:

- Although the entire EUS was considered at the time of the SEP study, attention was focused on the areas around the SEP sites--mainly in the Central United States (CUS) and New England. The zonation of other areas was not performed with the same level of detail.
- The peer review process, both by our Peer Review Panel and other reviewers, identified some areas of possible improvements in the SEP methodology.
- Since the SEP zonations were provided by our EUS Seismicity Panel in early 1979, a number of important studies had been completed and several significant EUS earthquakes had occurred which could impact the Panel members' understanding of the seismotectonics of the EUS.
- Our understanding of the EUS ground motion had improved since the time the SEP study was performed.

By the time our methodology was firmed up, the expert opinions collected and the calculations performed (i.e. by 1985), the Electric Power Research Institute (EPRI) had embarked on a parallel study.

We performed a comparative study, Bernreuter et. al., (1987), to help in understanding the reasons for differences in results between the LLNL and the EPRI studies. The three main differences were found to be: (1) the minimum magnitude value of the earthquakes contributing to the hazard in the EUS, (2) the ground motion attenuation models, and (3) the fact that LLNL accounted for local site characteristics and EPRI did not. Several years passed between the 1985 study and the application of the methodology to all the sites in the EUS. In recognition of the fact that during that time a considerable amount of research in seismotectonics and in the field of strong ground motion prediction, in particular with the development of the so called random vibration or stochastic approach, NRC decided to follow our recommendations and have a final round of feedback with all our experts prior to finalizing the input to the analysis.

In addition, we critically reviewed our methodology which lead to minor improvements and we also provided an extensive account of documentation on the ways the experts interpreted our questionnaires and how they developed their answers. Some of the improvements were necessitated by the recognition of the fact that the results of our study will be used, together with results from other studies such as the EPRI study or the USGS study, to evaluate the relative hazard between the different plant sites in the EUS.

This report includes eight volumes:

> Volume I provides an overview of the methodology we developed for this project. It also documents the final makeup of both our Seismicity and Ground Motion Panels, and documents the final input from the members of both panels used in the analysis. Comparisons are made between the new results and previous results.

Volumes II to V provide the results for all the active nuclear power plant sites of the EUS divided into four batches of approximately equal size and of sites roughly located in the four main geographical regions of the EUS (NE, SE, NC and SC). A regional discussion is given in each of Vols. II to V.

Volume VI emphasizes important sensitivity studies, in particular the sensitivity of the results to correction for local site conditions and G-Expert 5's ground motion model. It also contains a summary of the results and provides comparisons between the sites within a common region and for sites between regions.

Volume VII contains unaltered copies of the ten questionnaires used from the beginning of the 1985 study to develop the complete input for this analysis.

After the bulk of the work was completed and draft reports for Vols. I-VII were written, additional funding became available.

Volume VIII contains the hazard result for the 12 sites which were primarily rock sites but which also had some structures founded on shallow soil. These results supplement the results given in Vols. II to V where only the primary soil condition at the site was used.

List of Abbreviations and Symbols

A	Symbol for Seismicity Expert 10 in the figures displaying the results for the S-Experts
ALEAS	Computer code to compute the BE Hazard and the CP Hazard for each seismicity expert
AM	Arithmetic mean
AMHC	Arithmetic mean hazard curve
B	Symbol for Seismicity Expert 11 in the figures displaying the results for the S-Experts
BE	Best estimate
BEHC	Best estimate hazard curve
BEUHS	Best estimate uniform hazard spectrum
BEM	Best estimate map
C	Symbol for Seismicity Expert 12 in the figures displaying the results for the S-Experts
COMAP	Computer code to generate the set of all alternative maps and the discrete probability density of maps
COMB	Computer code to combine BE hazard and CP hazard over all seismicity experts
CP	Constant percentile
CPHC	Constant percentile hazard curve
CPUHS	Constant percentile uniform hazard spectrum
CUS	Central United States, roughly the area bounded in the west by the Rocky Mountains and on the east by the Appalachian Mountains, excluding both mountain systems themselves
CZ	Complementary zone
D	Symbol for Seismicity Expert 13 in the figures displaying the results for the S-Experts
EPRI	Electric Power Research Institute

EUS	Used to denote the general geographical region east of the Rocky Mountains, including the specific region of the Central United States (CUS)
g	Measure of acceleration: 1g = 9.81m/s/s = acceleration of gravity
G-Expert	One of the five experts elicited to select the ground motion models used in the analysis
GM	Ground motion
HC	Hazard curve
I_o	Epicentral intensity of an earthquake relative to the MMI scale
I_s	Site intensity of an earthquake relative to the MMI scale
LB	Lower bound
LLNL	Lawrence Livermore National Laboratory
M	Used generically for any of the many magnitude scales but generally m_b, $m_b(Lg)$, or M_L.
M_L	Local magnitude (Richter magnitude scale)
M_b	True body wave magnitude scale, assumed to be equivalent to $m_b(Lg)$ (see Chung and Bernreuter, 1981)
$m_b(Lg)$	Nuttli's magnitude scale for the Central United States based on the Lg surface waves
M_S	Surface wave magnitude
MMI	Modified Mercalli Intensity
M_o	Lower magnitude of integration. Earthquakes with magnitude lower than M_o are not considered to be contributing to the seismic hazard
NC	North Central; Region 3
NE	North East; Region 1
NRC	Nuclear Regulatory Commission
PGA	Peak ground acceleration
PGV	Peak ground velocity

PRD	Computer code to compute the probability distribution of epicentral distances to the site
PSRV	Pseudo relative velocity spectrum. Also see definition of spectra below
Q	Seismic quality factor, which is inversely proportional to the inelastic damping factor.
Q1	Questionnaire 1 - Zonation (I)
Q2	Questionnaire 2 - Seismicity (I)
Q3	Questionnaire 3 - Regional Self Weights (I)
Q4	Questionnaire 4 - Ground Motion Models (I)
Q5	Questionnaire 5 - Feedback on seismicity and zonation (II)
Q6	Questionnaire 6 - Feedback on ground motion models (II)
Q7	Questionnaire 7 - Feedback on zonation (III)
Q8	Questionnaire 8 - Seismicity input documentation
Q9	Questionnaire 9 - Feedback on seismicity (III)
Q10	Questionnaire 10 - Feedback on ground motion models (III)
R	Distance metric, generally either the epicentral distance from a recording site to the earthquake or the closest distance between the recording site and the ruptured fault for a particular earthquake.
Region 1	(NE): North East of the United States, includes New England and EOltern Canada
Region 2	(SE): South East United States
Region 3	(NC): North Central United States, includes the Northern Central portions of the United States and Central Canada
Region 4	(SC): Central United States, the Southern Central portions of the United States including Texas and Louisiana
RP	Return period, in years
RV	Random vibration. Abbreviation used for a class of ground motion models also called stochastic models.

S	Site factor used in the regression analysis for G-Expert 5's GM model: $S = 0$ for deep soil, $S = 1$ for rock sites
SC	South Central; Region 4
SE	South East; Region 2
S-Expert	One of the eleven experts who provide the zonations and seismicity models used in the analysis
SEP	Systematic Evaluation Program
SHC	Seismic Hazard Characterization
SHCUS	Seismic Hazard Characterization of the United States
SN	Site Number
Spectra	Specifically in this report: attenuation models for spectral ordinates were for 5% damping for the pseudo-relative velocity spectra in PSRV at five frequencies (25, 10, 5, 2.5, 1 Hz).
SSE	Safe Shutdown Earthquake
SSI	Soil-structure-interaction
SSMRP	Seismic Safety Margins Research Program
UB	Upper bound
UHS	Uniform hazard spectrum (or spectra)
USGS	United States Geological Survey
WUS	The regions in the Western United States where we have strong ground motion data recorded and analyzed

Executive Summary: Volume IV

The impetus for this study came from two unrelated needs of the Nuclear Regulatory Commission (NRC). One stimulus arose from the NRC funded "Seismic Safety Margins Research Programs" (SSMRP). The SSMRP's task of simplified methods needed to have available data and analysis software necessary to compute the seismic hazard at any site located in the eastern United States (EUS) in a form suitable for use in probabilistic risk assessment (PRA). The second stimulus was the result of the NRC's discussions with the U.S. Geological Survey (USGS) regarding the USGS's proposed clarification of their past position with respect to the 1886 Charleston earthquake. The USGS clarification was finally issued on November 18, 1982, in a letter to the NRC, which states that:

> "Because the geologic and tectonic features of the Charleston region are similar to those in other regions of the eastern seaboard, we conclude that although there is no recent or historical evidence that other regions have experienced strong earthquakes, the historical record is not, of itself, sufficient ground for ruling out the occurrence in these other regions of strong seismic ground motions similar to those experienced near Charleston in 1886. Although the probability of strong ground motion due to an earthquake in any given year at a particular location in the eastern seaboard may be very low, deterministic and probabilistic evaluations of the seismic hazard should be made for individual sites in the eastern seaboard to establish the seismic engineering parameters for critical facilities."

Anticipation of this letter led the Office of Nuclear Reactor Regulation to jointly fund a project with the Office of Nuclear Regulatory Research. The results were presented in Bernreuter et al. in 1985 and the objectives were:

1. to develop a seismic hazard characterization methodology for the entire region of the United States east of the Rocky Mountains (Referred to as EUS in this report).

2. to apply the methodology to selected sites to assist the NRC staff in their assessment of the implications in the clarification of the USGS position on the Charleston earthquake, and the implications of the occurrence of the recent eastern U.S. earthquakes in New Brunswick and New Hampshire.

The methodology used in that 1985 study evolved from two earlier studies LLNL performed for the NRC. One study, Bernreuter and Minichino (1983), was part of the NRC's Systematic Evaluation Program (SEP) and is simply referred hereafter to as the SEP study. The other study was part of the SSMRP.

At the time (1980-1985), an improved hazard analysis methodology and EUS seismicity and ground motion data set were required for several reasons:

- Although the entire EUS was considered at the time of the SEP study, attention was focused on the areas around the SEP sites--mainly in the Central United States (CUS) and New England. The zonation of other areas was not performed with the same level of detail.

- The peer review process, both by our Peer Review Panel and other reviewers, identified some areas of possible improvements in the SEP methodology.

- Since the SEP zonations were provided by our EUS Seismicity Panel in early 1979, a number of important studies have been completed and several significant EUS earthquakes have occurred which could impact the Panel members' understanding of the seismotectonics of the EUS.

- Our understanding of the EUS ground motion had improved since the time the SEP study was performed.

By the time our methodology was firmed up, the expert opinions collected and the calculations performed (i.e. by 1985), the Electric Power Research Institute (EPRI) had embarked in a paralleled study.

We performed a comparative study (Bernreuter et al. 1987) whose purpose was to help in understanding the reasons for differences in results between the LLNL and the EPRI study (EPRI 1985a and 1985b). The three main differences were found to be (1) the minimum magnitude value of the earthquakes contributing to the hazard in the EUS, (2) the ground motion attenuation models, and (3) the fact that LLNL accounted for local site characteristics and EPRI did not. Several years passed between the 1985 study and the time when NRC actually decided to apply the methodology to all the sites in the EUS. In recognition of the fact that during that time a considerable amount of research in seismotectonics and in the field of strong ground motion prediction, in particular with the development of the so called random vibration or stochastic approach, NRC decided to follow our recommendations and have a final round of feedback with all our experts prior to finalizing the input to the analysis.

In addition, we critically reviewed our methodology which lead to minor improvements and we also provided an extensive account of documentation on the ways the experts interpreted our questionnaires and how they developed their answers. Some of the improvements were necessitated by the recognition of the fact that the results of our study will be used, together with results from other studies such as the EPRI study or the USGS study, to evaluate the relative hazard between the different plant sites in the EUS.

This volume (volume IV) is one of eight volumes where the methodology and the results of the analysis are presented. The analysis was performed for a total of 69 different geographic locations. These sites were divided into four groups (batches) of approximately equal size. Volume IV presents the results for the group of sites roughly located in the north central part of the EUS. It contains 16 sites.

The results are presented individually for each site together with comments. The seismic hazard results presented here account for earthquakes of magnitude 5 or above only, and a set of calculations was made to provide an estimate of the seismic hazard created at each of the sites by the earthquakes of magnitude between 3.75 and 5.

In addition, a discussion on uncertainty, comparison between sites, sensitivity to site location and a discussion on the factors influencing the distribution of the contributing zones, is presented in Section 3.
The other volumes provide an extensive description of the methodology (Volume I), the results for the other groups of sites (Volume II, III and V), a summary and some comparisons between sites and groups of sites (Volume VI). A copy of all the questionnaires used in the analysis to develop the input is given in Volume VII, and finally, an additional volume (Volume VIII) was created to provide the results for the sites at which several soil conditions were present since Volumes II to V only contained the results for a single soil condition at each of the 69 sites.

1. INTRODUCTION

In this Volume we present the seismic hazard estimates for the 16 sites in Batch 2 listed in Table 1.1 and plotted in Fig. 1.1. The seismic hazard results for the Batch 3 sites are based on:

- The zonation and seismicity inputs provided by our eleven S-Experts listed in Table 1.2.
- The ground motion models (peak ground acceleration (PGA) models and 5 percent damped velocity spectral models) provided by our five G-Experts listed in Table 1.3.
- The methodology we developed is described in Vol. I of this report and in other documents referenced in Vol. 1.

The results presented in his report differ from our previous results Bernreuter et al. (1984, 1985, 1987) because for the following reasons:

- This analysis used the final updated input from our S and G-Experts given in Section 3 and Appendix B of Vol. I. As discussed in Vol. I, S-Experts 3,6,7 and 12 provided completely new zonations and seismicity parameters, S-Experts 4,10,11 and 13 modified some of their zones and seismicity parameters, S-Experts 1,2 and 5 did not make any changes, and the G-Experts significantly changed their ground motion models. The seismic zonation maps are reproduced here in Appendix B.
- A lower bound of integration of $m_b = 5.0$ was used, i.e., we only included the contribution from earthquakes with magnitude 5.0 and greater. In our previous reports, Bernreuter et Al. (1984, 1985), we used a lower bound of 3.75. This change has a significant impact on the results as discussed in Bernreuter et Al. (1987). A set of plots for every site giving an indication of how much the earthquakes in the magnitude range 3.75 to 5 would contribute to the seismic hazard estimates is given in the report.

Corrections for the soil conditions at each site have been included using the approach outlined in Section 3.7 of Vol. I. However, it is important to note that each site is put in a single fixed site soil category as listed in Table 1.1. At some sites, some structures, (e.g., the main containment buildings) are founded on rock but some structures are founded on shallow soil (e.g. tanks, pump buildings). The seismic hazard estimates given in this report are at the free surface and in the case of shallow rock sites, it is at the free surface of the rock with the soil removed. Thus for these rock sites which have a few structures founded on shallow soil the results presented here should then be corrected for the shallow soil amplification effects as described in Vol. VI before the results given in this report are applied to the structures founded on soil. If all structures are founded on the same soil condition, then no added correction is needed.

Section 2 of this report contains the results for each site and, some site specific discussion. In section 3 of this report we make regional observations and comparisons between sites as well as some comments on sensitivity to site regional location and distance bins contribution. In Vol. VI we reach overall conclusions based on the regional results presented in this volume and Vols. II, III and V, and Volume VII provides an unaltered copy of all the questionnaires used in this analysis to develop the input.

TABLE 1.1

SITES AND SOIL CATEGORY USED FOR EACH SITE IN BATCH 3

	SITE NAME	Map (1) KEY	SOIL CATEGORY (2)
1.	Beaver Valley	1	Sand-like 1
2.	Big Rock Point	2	Till-like 1
3.	Braidwood	3	Rock
4.	Byron	4	Rock**
5.	Clinton	5	Till-like 2
6.	Cook	6	Sand-like 2
7.	Davis Besse	7	Rock
8.	Dresden	8	Rock
9.	Fermi	9	Rock
10.	Kewaunee	A	Till-like 2
11.	LaSalle	B	Till-like 2
12.	Palisades	C	Sand-like 2
13.	Perry	D	Rock
14.	Point Beach	E	Till-like 1
15.	Quad Cities	F	Rock
16.	Zion	G	Sand-like 2

(1) Key used on Fig. 1.1.

(2) Site categories as given in Table 1.4 (repeated from Table 3.9 of Vol. I)

(**) Have structures founded in shallow soil.

TABLE 1.2

FINAL EUS ZONATION AND SEISMICITY PANEL MEMBERS
(S-Panel)

Professor Gilbert A. Bollinger

Mr. Richard J. Holt

Professor Arch C. Johnston

Dr. Alan L. Kafka

Professor James E. Lawson

Professor L. Tim Long

Professor Otto W. Nuttli

Dr. Paul W. Pomeroy

Dr. J. Carl Stepp

Professor Ronald L. Street

Professor M. Nafi Toksöz

TABLE 1.3

FINAL EUS GROUND MOTION MODEL PANEL MEMBERS (G-Panel)

Dr. David M. Boore

Dr. Kenneth Campbell

Professor Mihailo Trifunac

Dr. John Anderson

Dr. John Dwyer

TABLE 1.4
DEFINITION OF THE EIGHT SITE CATEGORIES

	CATEGORY	DEPTH
Generic Rock		
(1)	Rock	N/A
Sand Like		
(2) Sand 1	S1	25 to 80 ft.
(3) Sand 2	S2	80 to 180 ft.
(4) Sand 3	S3	180 to 300 ft.
Till-Like		
(5) Till 1	T1	25 to 80 ft.
(6) Till 2	T2	80 to 180 ft.
(7) Till 3	T3	180 to 300 ft.
Deep Soil		
(8)	Deep Soil	N/A

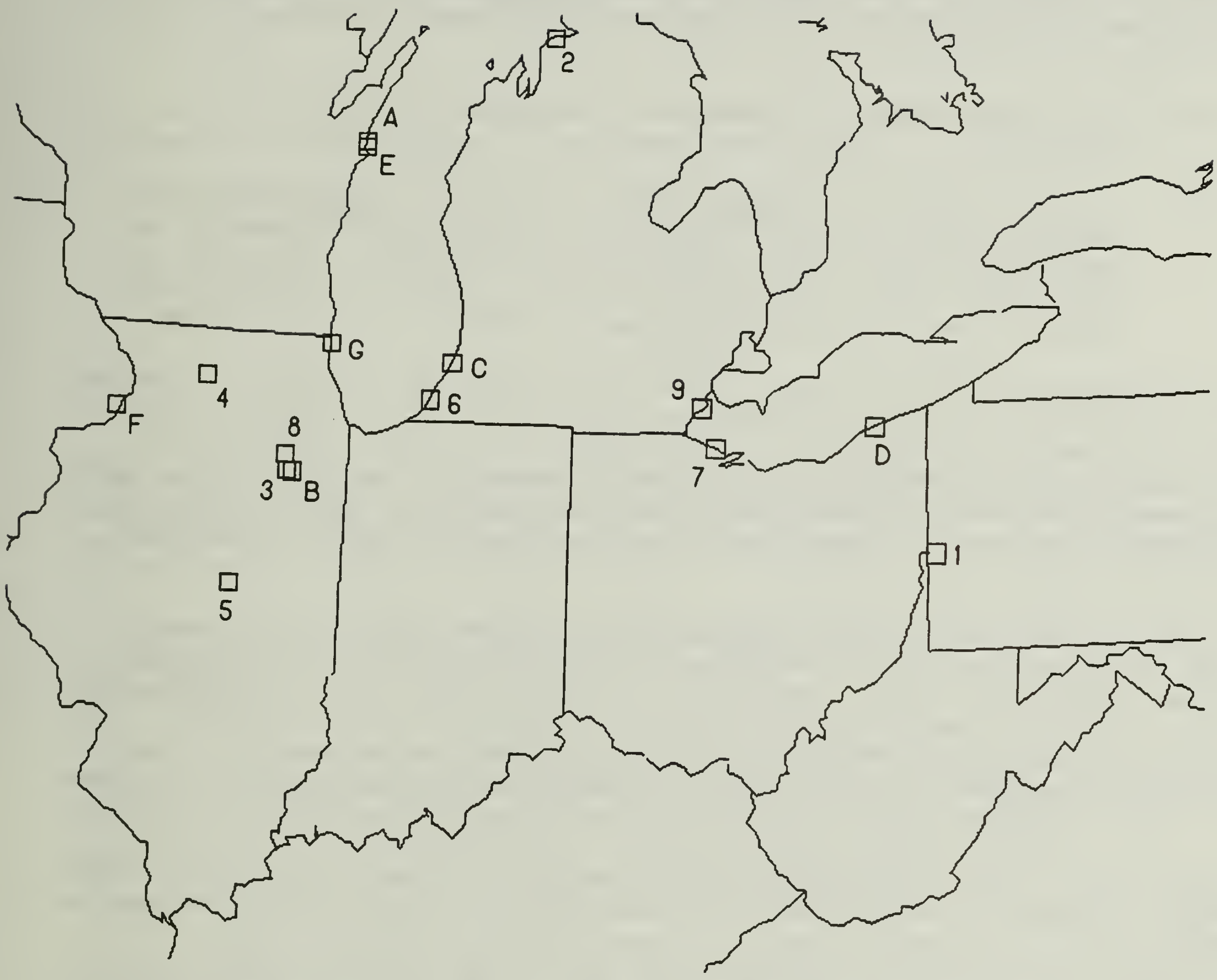


Figure 1.1 Map showing the location of Batch 3 sites contained in Volume IV of this report. Map symbols are given in Table 1.1.

2. RESULTS AND SITE SPECIFIC DISCUSSION

2.0 General Introduction

In sections 2.1 to 2.17 we provide the results for the sites listed in Table 1.1. Using a uniform format for each site (i.e. each section) we first present table 2.SN.1 (where "SN" stands for Site Number) providing the following information:

- Soil category used in the analysis to correct for local site conditions.
- For each S-Expert the table 2.SN.1 provides a listing of the four seismic zones which contribute most to the hazard in terms of the peak ground acceleration (PGA) at both lower PGA (0.125g) and at higher PGA (0.6g) values. The zone ID's listed in the tables are keyed to the S-Experts' maps given in Appendix B of this Volume.

The contribution of various zones given in the table for each site is limited only to the contribution to the best estimate hazard curves (BEHCs). That is, only the zones on the BE map (i.e. those zones which have a probability of existence of 0.5 or greater) and only the BE PGA models are used. This, as is discussed in Section 3.3, is a limitation that should be kept in mind as in a few cases zones with a probability of existence of less than 0.5 which may contribute might not be listed.

The table is followed by ten figures, 2.SN.1 to 2.SN.10 (SN = Site Number given in Table 1.1). The first three figures, Figs. 2.SN.1 - 2.SN.3 give various PGA hazard curves. The next six figures, Figs. 2.SN.4 - 2.SN.9 give various 5 percent damped relative velocity spectra for various return periods. It should be noted that the spectral calculations have only been made at five periods, 0.04s, 0.1s, 0.2s, 0.4s and 1.0s and straight lines have been used to connect these points to get the shapes plotted.

Figures 2.SN.1 give a comparison between the best estimate hazard curve (BEHC) and the arithmetical mean hazard curve (AMHC) for the peak ground acceleration (PGA).

The BEHC and the AMHC are aggregated over all S- and G-Experts and include the experts' self weights. Reference should be made to Section 2 and Appendix C of Vol. 1 for a discussion about these two estimators. Briefly, in our elicitation process we asked each S-expert to indicate which set of zones he considered his "best estimate" in the sense that it represented the mode of the distribution of all of his choices and similarly for the best estimate values for all of the seismicity parameters for each zone. We also asked each G-Expert to indicate which ground motion model represented his best estimate model. Then, as indicated in Vol. I, the set of best estimate zones and seismicity parameters are used with each of the best estimate ground motion models to generate 55 BEHCs'. These 55 curves are then aggregated using both the S- and G-Experts' self weights. The AMHC is generated in the usual manner using all 2750 simulations of the Monte Carlo analysis.

Figures 2.SN.2 give the BEHC for each S-Expert aggregated over the five G-Experts. Whenever individual S-Experts' hazard curves are plotted they are denoted by the plot key given in Table 2.0. Figures 2.SN.2 give a measure of the range of difference of opinion between the eleven S-Experts.

Figures 2.SN.3 give the 15th, 50th and 85th constant percentile hazard curves (CPHCs) based on all 2750 simulations and give a measure of the overall uncertainty.

Figures 2.SN.4 give the contribution to the BEHC (aggregated over all S- and G-Experts) for earthquakes in four magnitude ranges:

Curve Number	Magnitude Range
1	$3.75 \leq m_b \leq 5$
2	$5 \leq m_b \leq 5.75$
3	$5.75 \leq m_b \leq 6.5$
4	$6.5 \leq m_b$

The curves are useful to indicate the relative contribution of smaller, moderate and large earthquakes to the seismic hazard and how much higher the estimated seismic hazard would be if the contribution of smaller earthquakes in the range 3.75 to 5.0 were included.

Figures 2.SN.5 give the best estimate uniform hazard spectra (BEUHS) for return periods of 500,1000,2000,5000, and 10,000 years, aggregated over all S and G-Experts.

Figures 2.SN.6 give the 1000 year return period BEUHS for each of the S-Experts, aggregated over the G-Experts. The S-Experts' BEUHS are plotted using the symbols in Table 2.0. These plots give a good measure of the significance of the differences in opinion between the S-Experts.

Figures 2.SN.7,8,9 give the 15th, 50th and 85th constant percentile uniform hazard spectra (CPUHS) aggregated over all S and G-Experts for return periods of 500,1000 and 10,000 years. The spread between the 15th and 85th CPUHS gives a good measure of the overall uncertainty in the estimate of the seismic hazard at the site.

Figures 2.SN.10 give the 50th CPUHS for return periods of 500,1000,2000, 5000 and 10,000 years, aggregated over all S and G-Experts.

For some sites, such as Beaver Valley, additional figures (i.e., figures 2.SN.11, 2.SN.12 and 2.SN.13) were given to demonstrate specific points.

A separate discussion is given when some factors of interest are noted. In Section 3 comparisons between the sites and general observations are made.

TABLE 2.0

PLOT SYMBOL KEY USED FOR INDIVIDUAL S-EXPERTS ON FIGS. 2.SN.2 and 2.SN.6

Expert No.	Plot Symbol
1	1
2	2
3	3
4	4
5	5
6	6
7	7
10	A
11	B
12	C
13	D

2.1 BEAVER VALLEY

The Beaver Valley site's soil category is sand-like-1 and it is represented by the symbol "1" in Fig. 1.1. Table 2.1.1 and Figs. 2.1.1 through 2.1.10 give the basic results for the Beaver Valley site.

The BEHC is approximately the same as the median CPHC. It can be seen from Fig. 2.1.2 that there are indeed some low outliers in the set of simulated hazard curves; e.g., the BEHC for S-Expert 12 is significantly lower than for the other S-Experts. In addition, at PGA values greater than 0.3g S-Experts 4 and 5 BEHCs are lower than the BEHCs for the rest of the S-Experts. The wide spread between the median (see Fig. 2.1.3 and Fig. 2.1.1) and AMHC indicates the presence of some high outliers in the set of simulated hazard curves as well. Examination of the individual sets of BEHCs, AMHCs and CPHCs per S-Expert indicates that each S-Expert's uncertainty about the zonation and seismicity parameters was large, as can be seen from Fig. 2.1.11. In Fig. 2.1.11 we give the BEHC and AMHC for S-Expert 5. We see from Fig. 2.1.11 that there is a large spread between the AMHC and the BEHC. The spread between estimates of the seismic hazard for the Beaver Valley site for S-Expert 5 is due primarily to S-Expert 5's uncertainty about the seismicity parameters.

S-Expert 12's BEHC is much lower than the other S-Experts because as can be seen from the tables in Appendix B, of his CZ, which is the host zone for Beaver Valley, has a best estimate value of 5.0 for the upper magnitude cutoff. Thus the CZ does not contribute to the BEHC for S-Expert 12. Also Expert 12's zone 18 which is relatively near the site has an upper magnitude cutoff of 5.2. Thus zone 18 does not contribute much to S-Expert 12's BEHC. It should be noted if earthquakes in the range of 3.75 to 5.0 were included in the analysis that S-Expert 12's hazard curves would be significantly increased.

Generally the spread between BEHC per G-Expert for any given S-Expert is relatively small as shown in Fig. 2.1.12. The spread between the G-Experts' BEHCs is typical. The spread between the G-Experts' BEHCs is slightly larger for S-Experts 4, 5 and 12 as is illustrated in Fig. 2.1.13 when the BEHCs per G-Expert for S-Expert 5's input are plotted.

We see from Fig. 2.1.4 that small earthquakes contribute most to the BEHC for PGA at the Beaver Valley site. We see that if earthquakes in the magnitude range 3.75 to 5.0 were included that the BEHC for PGA would be significantly increased in the 0.05g to 0.6g range.

It can be seen from Table 2.1.1 that for most S-Experts the zone which contains the site is also the most significant contribution to the BEHC for the various S-Experts. The only departures are for S-Experts 3, 4 and 12. We have already indicated why the host zone does not contribute to S-Expert 12's BEHC. We see from the maps in Appendix B that the Beaver Valley site is very near S-Expert 3's zone 11. If the tables in Appendix B of Vol. 1 are examined it can be seen that the rate of seismicity is much higher in zone 11 than in the CZ for S-Expert 3. Thus, it is not surprising that zone 11 contributes

more to the BEHC for S-Expert 3 than the CZ even though the CZ is the host zone. The same is true for S-Expert 4 where we see that zone 27 is near the site and has a much higher rate of seismicity than the CZ for S-Expert 4.

TABLE 2.1.1

MOST IMPORTANT ZONES PER S-EXPERT FOR BEAVER VALLY

```
SITE SOIL CATEGORY  SAND-1

S-XPT  HOST            ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION
NUM.   ZONE              AT LOW PGA(0.125G)                                  AT HIGH PGA(0.60G)
----------------------------------------------------------------------------------------------------------
 1  ZONE 4      ZONE ID: ZONE 4     ZONE 19    ZONE 15    ZONE 9       ZONE 4     ZONE 15    ZONE 19    ZONE 9
                % CONT.:      86.         7.         3.        2.           95.         4.         1.        0.
----------------------------------------------------------------------------------------------------------
 2  COMP. ZO    ZONE ID: COMP. ZON  ZONE 18    ZONE 30    ZONE 27      COMP. ZON  ZONE 18    ZONE 30    ZONE 32
                % CONT.:      41.        27.        14.        9.           88.        10.         1.        1.
----------------------------------------------------------------------------------------------------------
 3  COMP. ZO    ZONE ID: ZONE 11    COMP. ZON  ZONE 5     ZONE 2       ZONE 11    COMP. ZON  ZONE 5     ZONE 13
                % CONT.:      92.         6.         1.        0.           89.        11.         0.        0.
----------------------------------------------------------------------------------------------------------
 4  ZONE 13     ZONE ID: ZONE 27    ZONE 12    ZONE  4    ZONE 13      ZONE 27    ZONE 13    ZONE 12    ZONE  4
                % CONT.:      57.        22.         6.        4.           53.        33.         8.        6.
----------------------------------------------------------------------------------------------------------
 5  COMP. ZO    ZONE ID: ZONE  6    ZONE 12    ZONE  9    ZONE 15      COMP. ZON  ZONE 15    ZONE 12    ZONE  9
                % CONT.:      57.        21.         8.        6.           71.        21.         4.        2.
----------------------------------------------------------------------------------------------------------
 6  ZONE 10     ZONE ID: ZONE 10    ZONE 9     ZONE 13    ZONE 7       ZONE 10    ZONE 9     COMP. ZON  ZONE 13
                % CONT.:      76.         8.         4.        2.           99.         1.         0.        0.
----------------------------------------------------------------------------------------------------------
 7  ZONE 41     ZONE ID: ZONE 41    ZONE 6     ZONE 7     ZONE 10      ZONE 41    ZONE 6     ZONE 7     ZONE 2 =
                % CONT.:      70.        14.        12.        1.           95.         4.         1.        0.
----------------------------------------------------------------------------------------------------------
10  ZONE 19     ZONE ID: ZONE 19 =  ZONE 26A   ZONE   5   ZONE   9     ZONE 19 =  ZONE 26A   ZONE   2   ZONE   3
                % CONT.:      90.         7.         1.        0.          100.         0.         0.        0.
----------------------------------------------------------------------------------------------------------
11  CZ = ZON    ZONE ID: CZ = ZONE  ZONE  5    ZONE  9    ZONE  8      CZ = ZONE  ZONE  5    ZONE  9    ZONE  8
                % CONT.:      65.        20.        10.        1.           97.         3.         1.        0.
----------------------------------------------------------------------------------------------------------
12  ZONE 4 =    ZONE ID: ZONE 19    ZONE 31    ZONE 23A   ZONE 20      ZONE 19    ZONE 15    ZONE 14    ZONE 13
                % CONT.:      32.        26.         8.        8.           54.        46.         0.        0.
----------------------------------------------------------------------------------------------------------
13  CZ 15       ZONE ID: CZ 15      ZONE  8    ZONE  7    ZONE  5      CZ 15      ZONE  5    ZONE  3    ZONE  4
                % CONT.:      97.         1.         1.        0.          100.         0.         0.        0.
----------------------------------------------------------------------------------------------------------
```

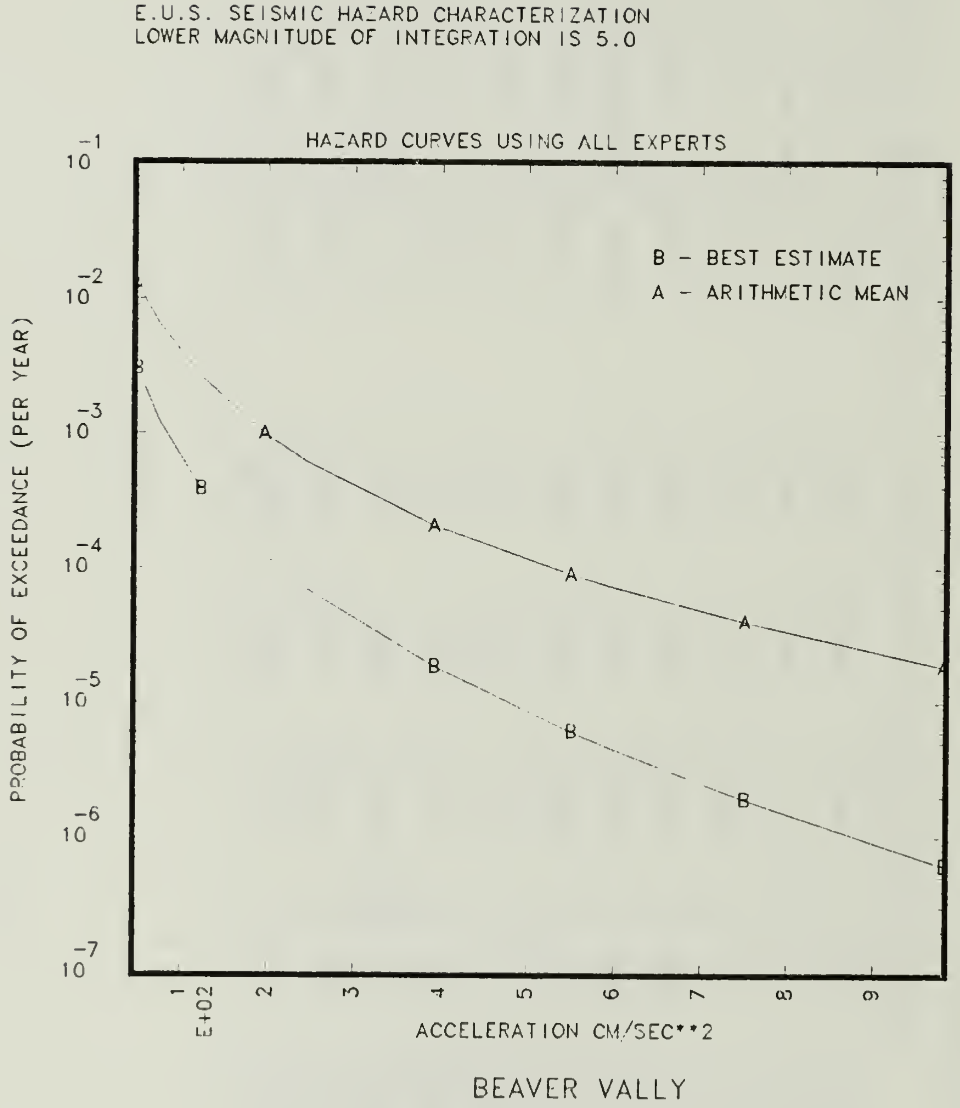


Figure 2.1.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Beaver Valley site.

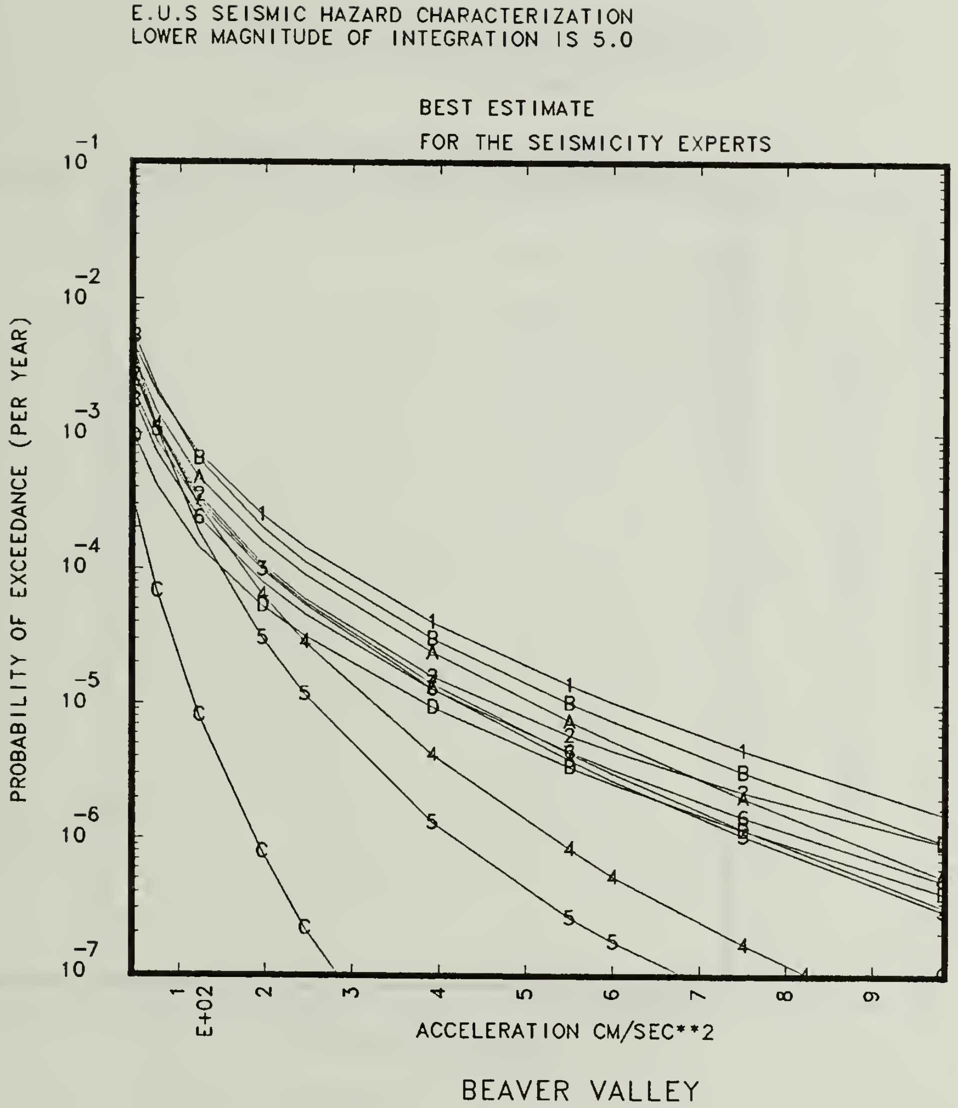


Figure 2.1.2 BEHCs per S-Expert combined over all G-Experts for the Beaver Valley site. Plot symbols given in Table 2.0.

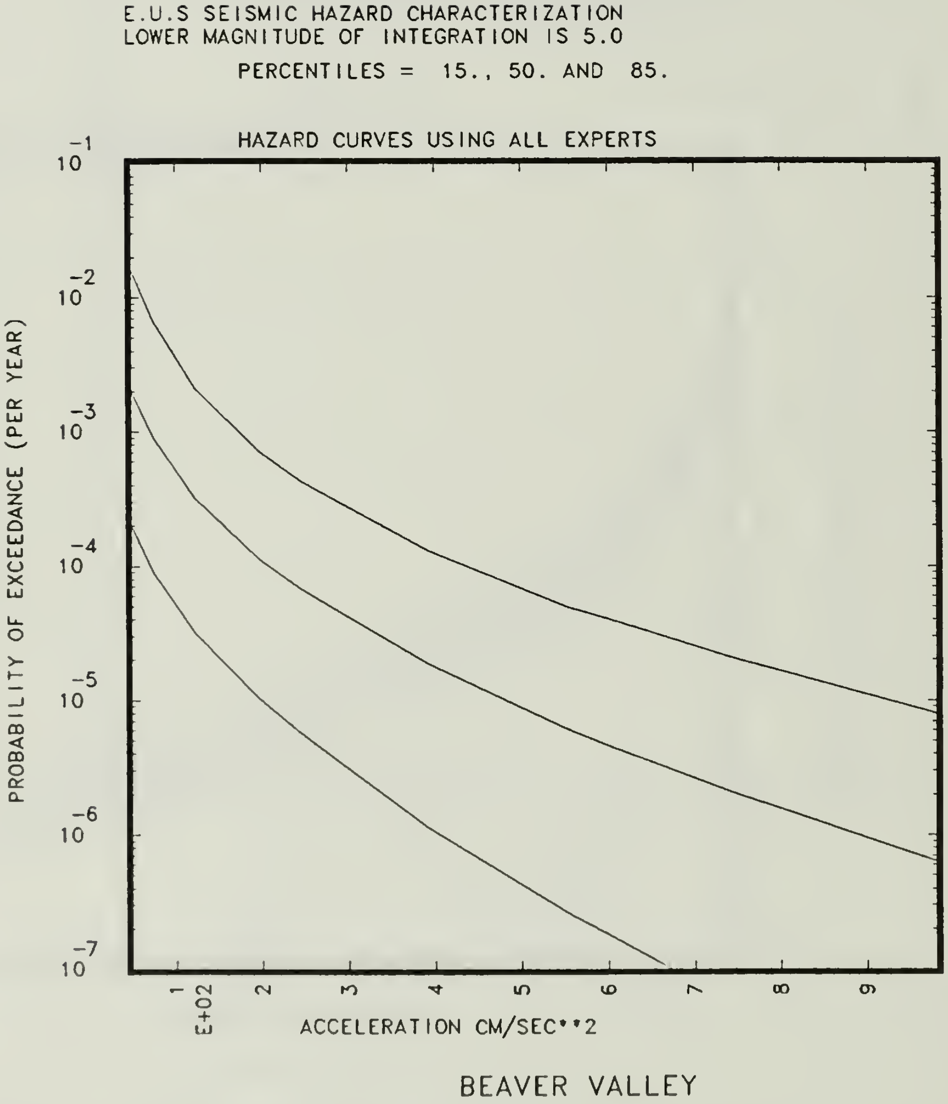


Figure 2.1.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Beaver Valley site.

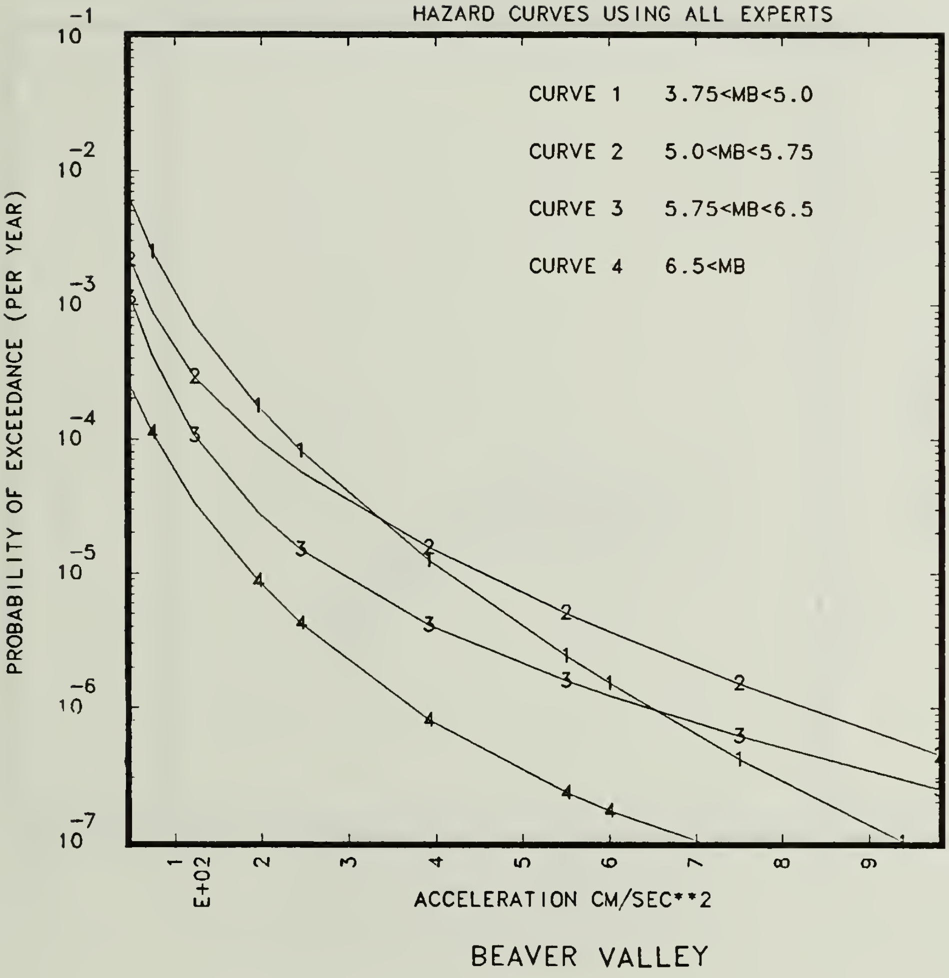


Figure 2.1.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Beaver Valley site.

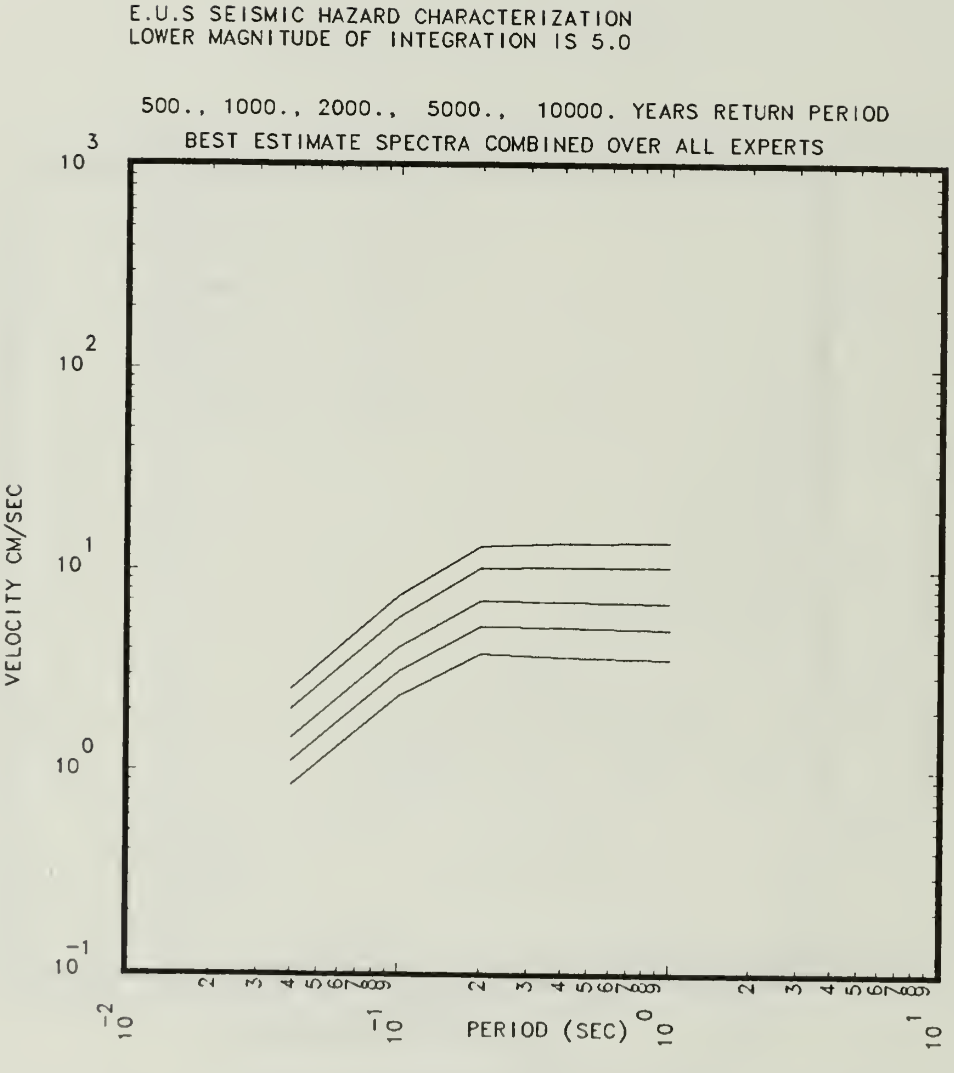


Figure 2.1.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Beaver Valley site.

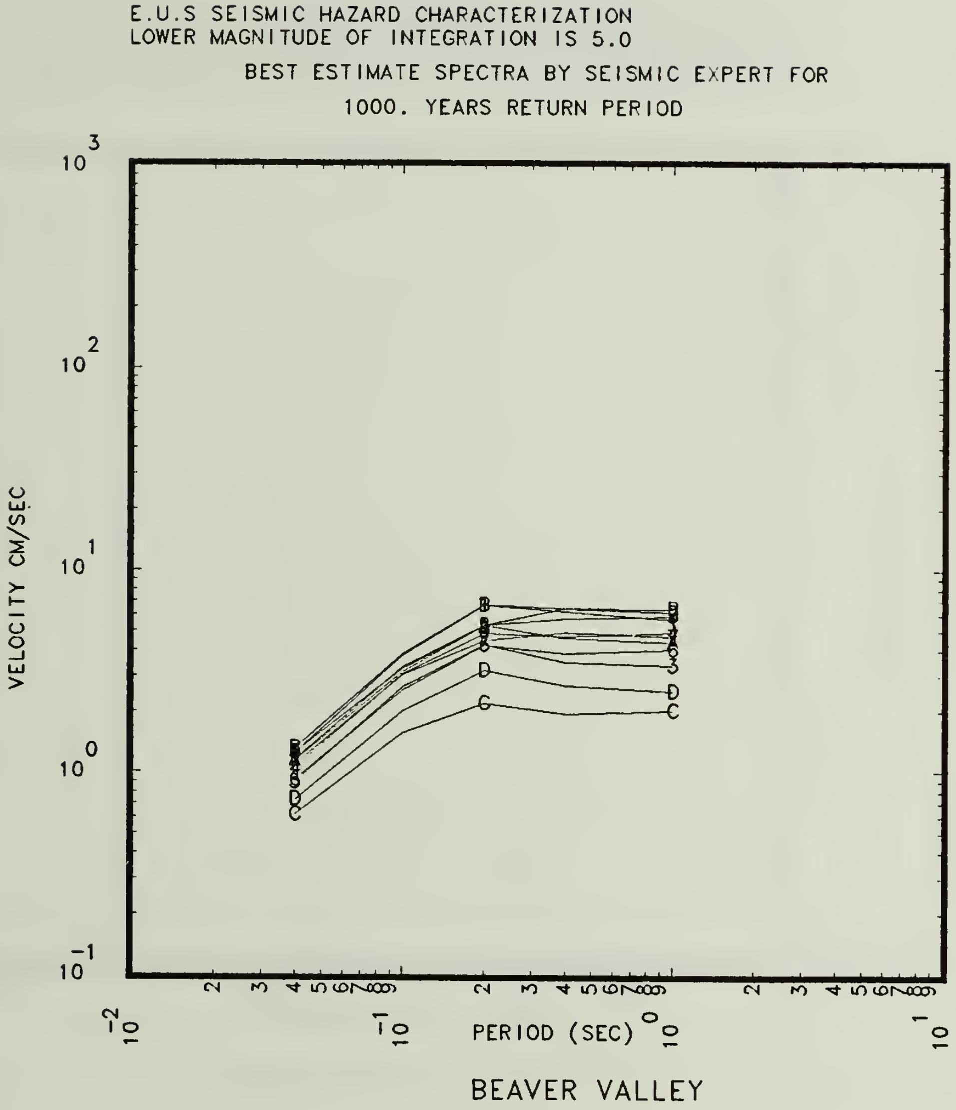


Figure 2.1.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Beaver Valley site. Plot symbols are given in Table 2.0.

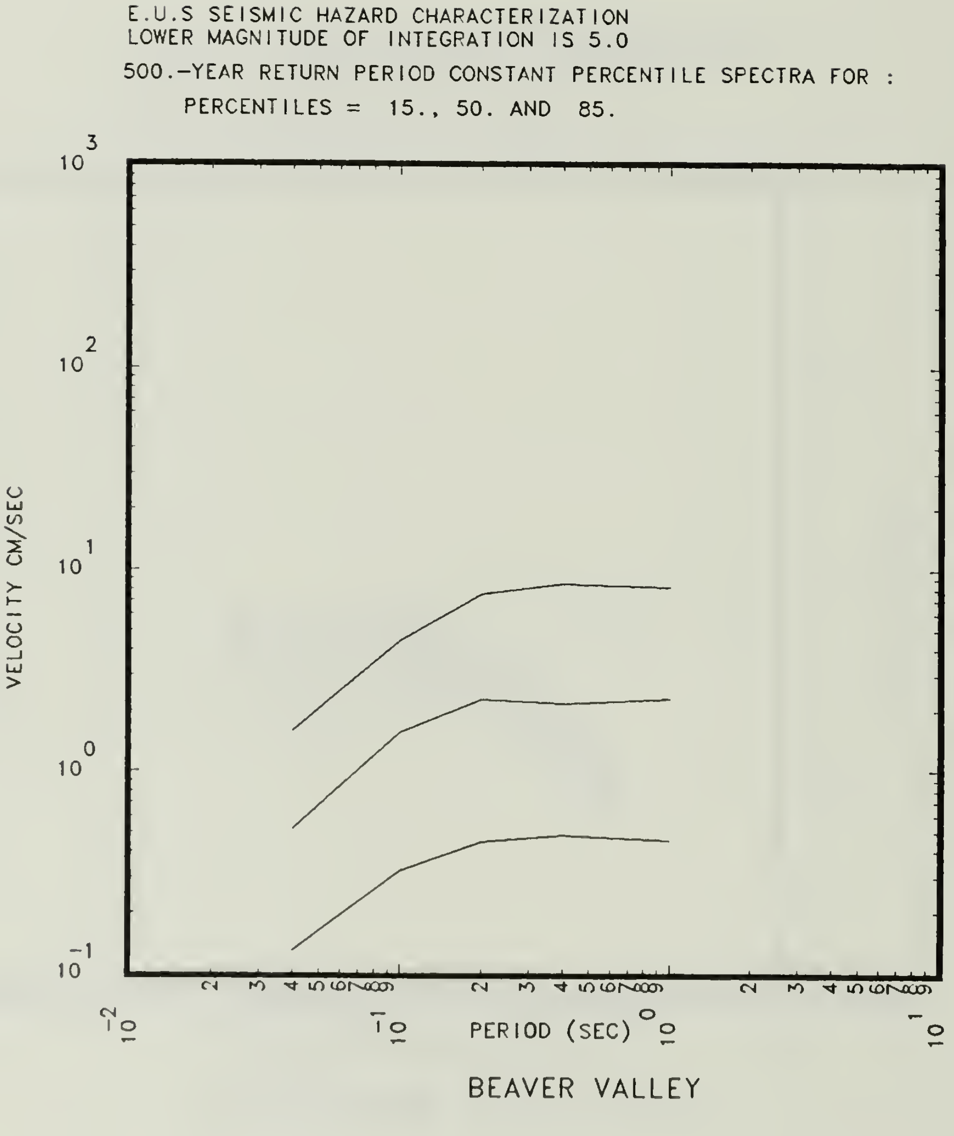


Figure 2.1.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Beaver Valley site.

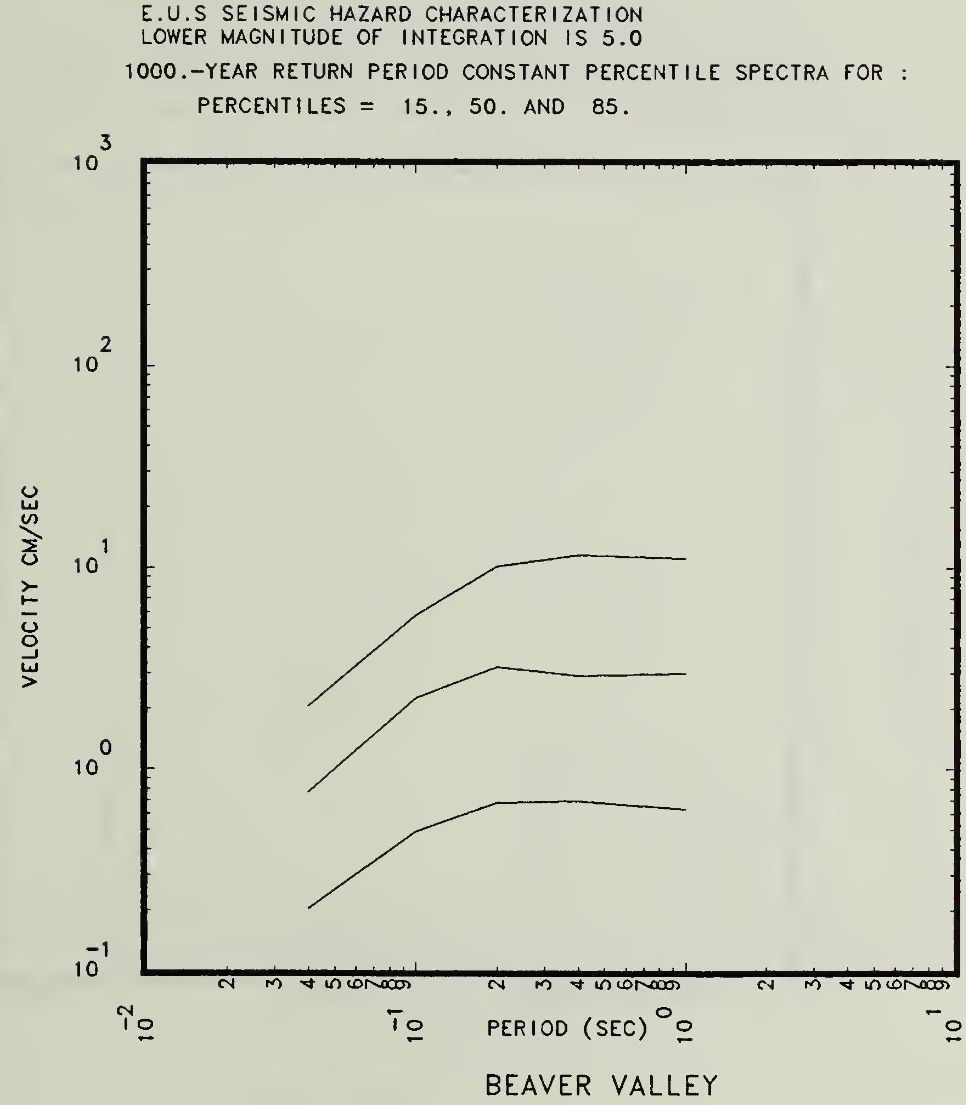


Figure 2.1.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Beaver Valley site.

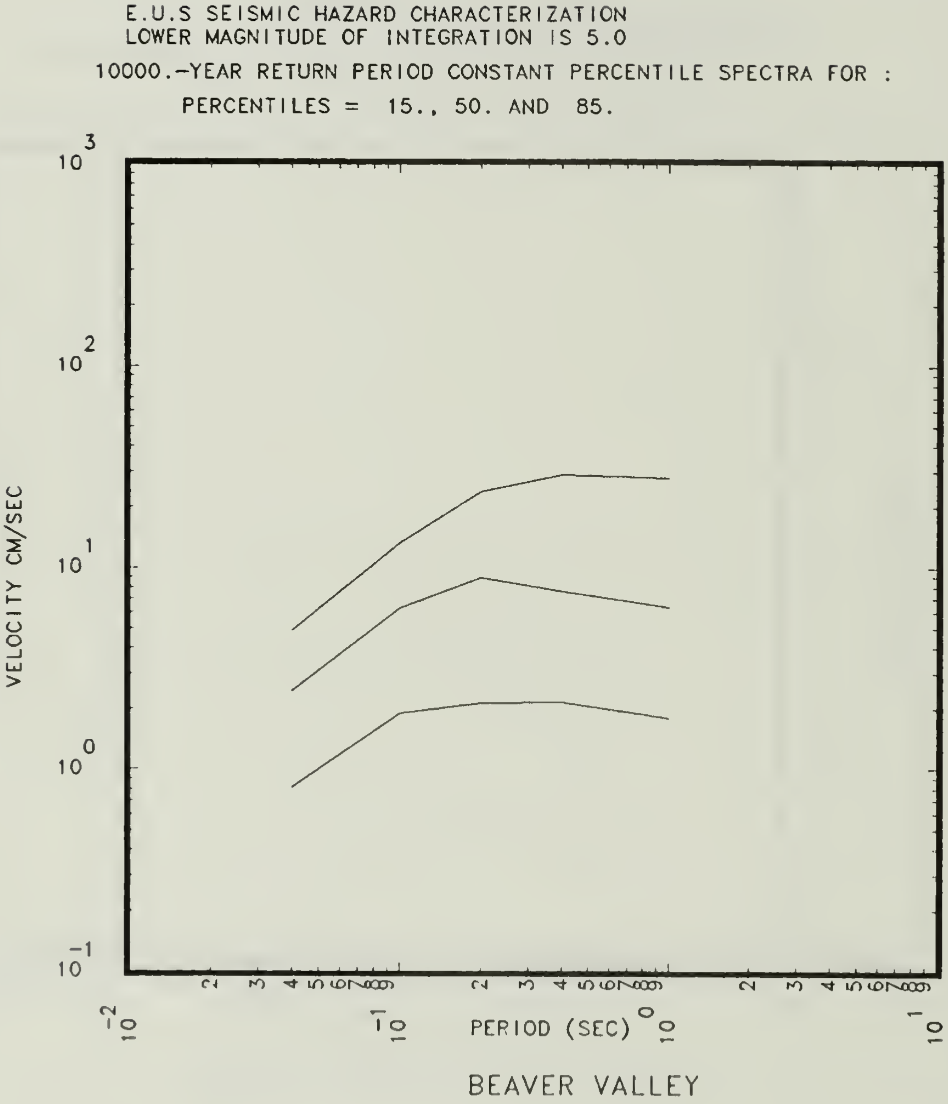


Figure 2.1.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Beaver Valley site.

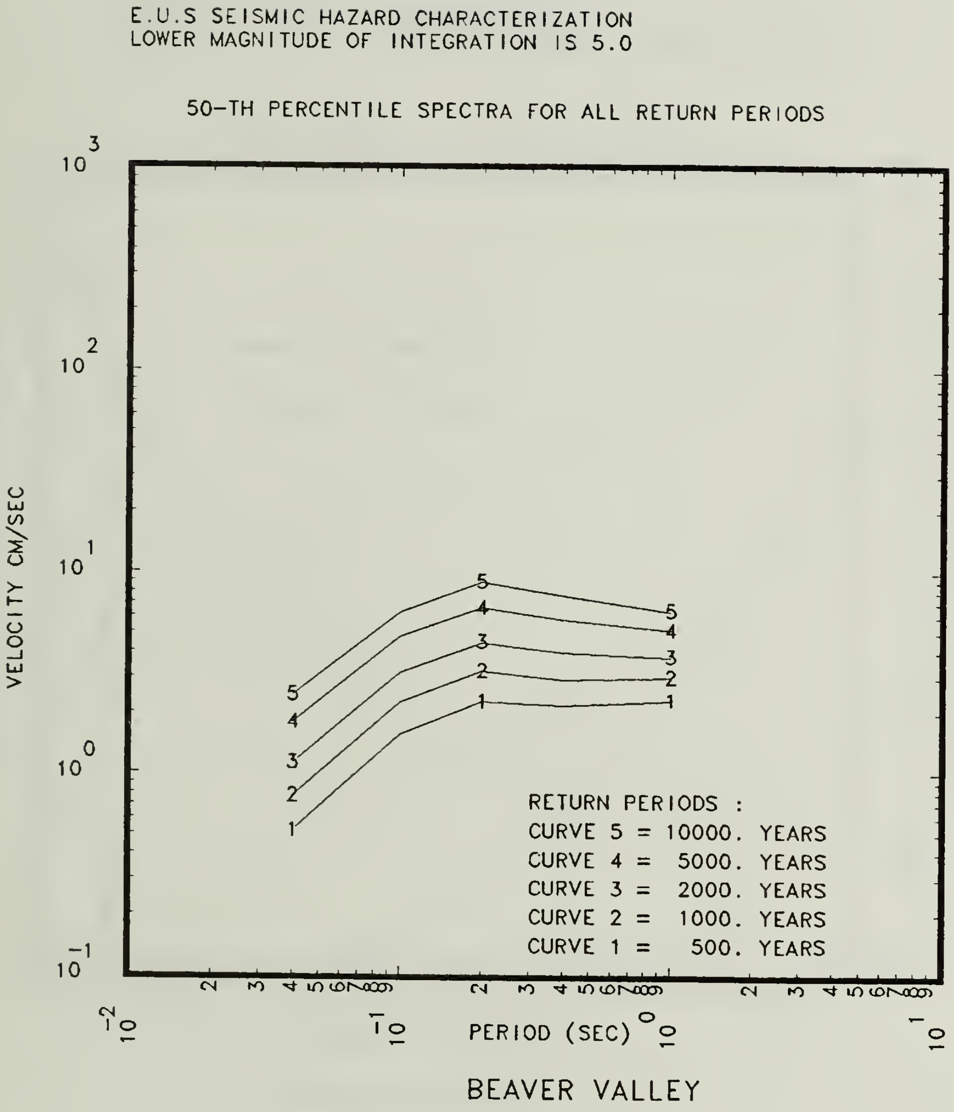


Figure 2.1.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Beaver Valley site.

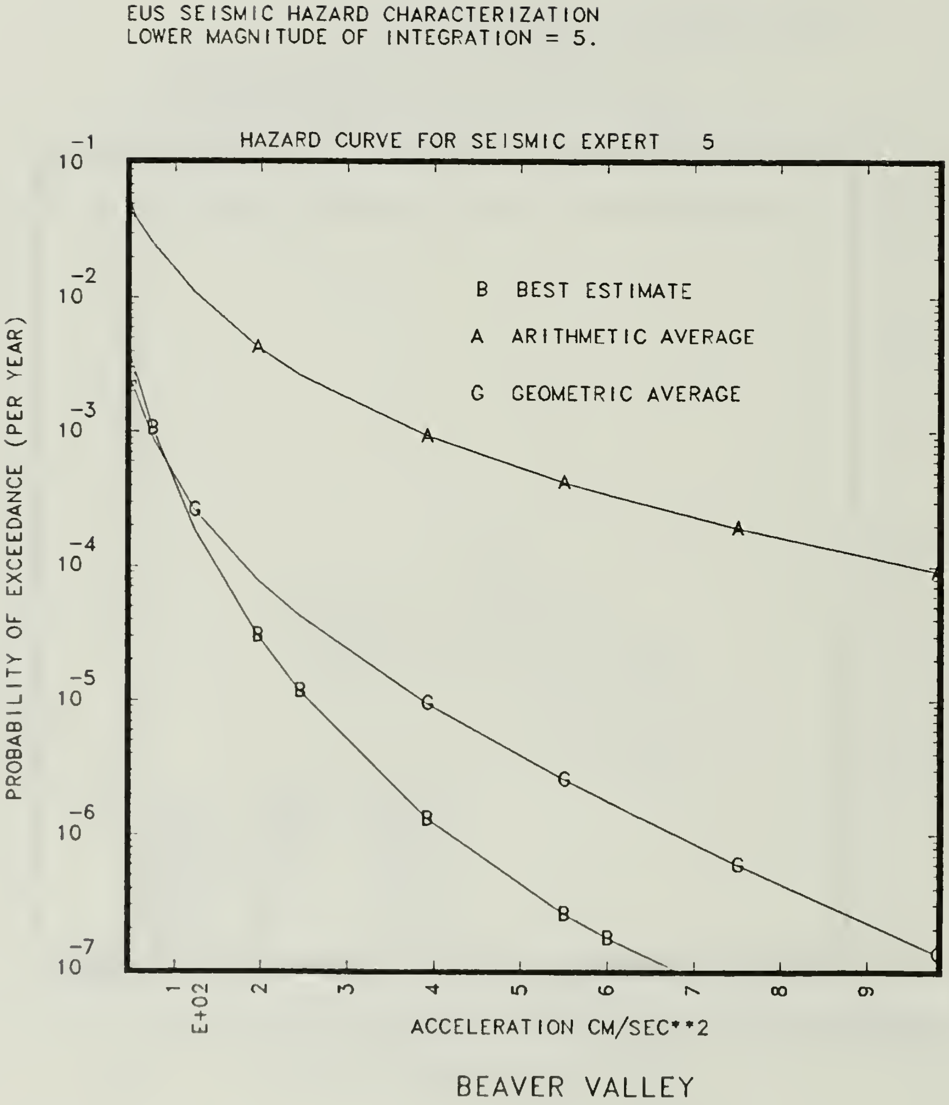


Figure 2.1.11 The BEHC, GMHC and AMEC for S-Expert 5 for the Beaver Valley site. Note the large spread between the AMHC and both the BE and GMHCs.

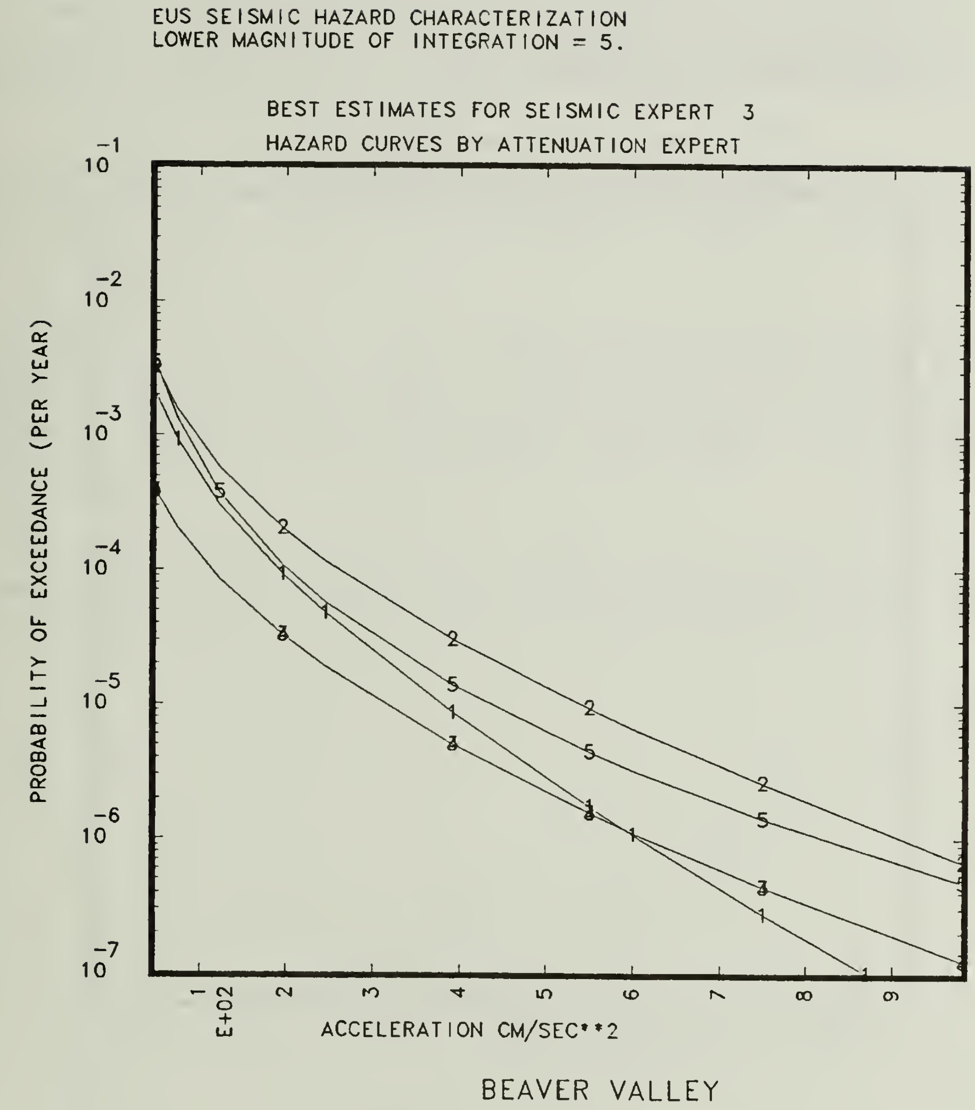


Figure 2.1.12 BEHCs per G-Expert for S-Expert 3's input for the Beaver Valley site. The spread between G-Experts' BEHCs is typical for the various S-Experts.

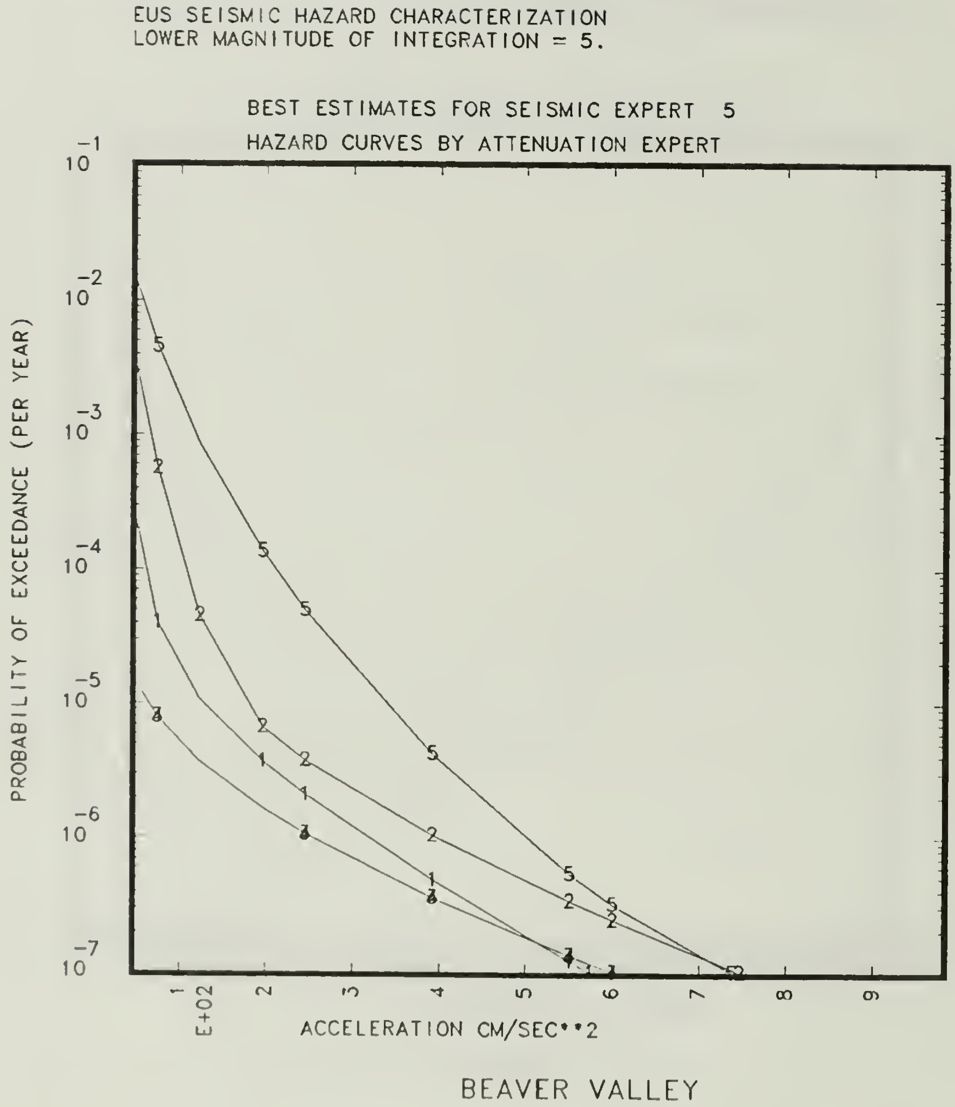


Figure 2.1.13 BEHCs per G-Expert for S-Expert 5's input for the Beaver Valley site.

2.2 BIG ROCK POINT

The Big Rock Point site's soil category is till-like 1 and it is represented by the symbol "2" in Fig. 1.1. Table 2.2.1 and Figs. 2.2.1 through 2.2.10 give the basic results for the Big Rock Point site.

The spread is similar to the spread seen for the Beaver Valley site. The BEHC is close to the median CPHC and the AMHC is somewhat higher than the 95th percentile CPHC. We see from Fig. 2.2.2 that there is a relatively wide spread between the S-Experts' BEHCs with S-Expert 12's BEHC being the lowest. S-Expert 12's BEHC is low for the Big Rock Point site for the same reasons that it was low at the Beaver Valley site. Thus the reader is referred to the discussion in Section 2.1.

The spread between S-Expert 5's BEHC and the AMHC is very similar to that shown in Fig. 2.1.11. The spread between the G-Experts' BEHCs per S-Expert is similar to that shown in Fig. 2.1.12 except for S-Experts 4 and 5 where it is similar to that shown in Fig. 2.1.13.

It can be seen from Fig. 2.2.4 that smaller magnitude earthquakes contribute most significantly to BEHC for PGA. It can be seen from Fig. 2.2.4 if earthquakes in the magnitude range of 3.75 to 5.0 were included that the BEHC for PGA would be significantly increased in the range of 0.05g to 0.5g and that large earthquakes do not significantly contribute to the BEHC for the Big Rock Point site.

We see from Table 2.2.1 that for all S-Experts except S-Expert 12 that the host zone is the zone that contributes most to the BEHC for PGA. This is consistent with importance of smaller magnitude earthquakes.

TABLE 2.2.1

MOST IMPORTANT ZONES PER S-EXPERT
FOR BIG ROCK POINT

SITE SOIL CATEGORY TILL-1

S-XPT. NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 18	ZONE ID:	ZONE 15	ZONE 18	ZONE 19	ZONE 11	ZONE 18	ZONE 15	ZONE 19	ZONE 4
		% CONT.:	34.	27.	18.	14.	80.	19.	1.	0.
2	COMP. ZO	ZONE ID:	COMP. ZON	ZONE 32	ZONE 20	ZONE 22	COMP. ZON	ZONE 32	ZONE 13	ZONE 15
		% CONT.:	97.	1.	1.	1.	100.	0.	0.	0.
3	COMP. ZO	ZONE ID:	COMP. ZON	ZONE 2	ZONE 15	ZONE 11	COMP. ZON	ZONE 2	ZONE 5	ZONE 11
		% CONT.:	80.	16.	2.	1.	99.	1.	0.	0.
4	ZONE 13	ZONE ID:	ZONE 13	ZONE 16	ZONE 6	ZONE 5	ZONE 13	COMP. ZON	ZONE 16	ZONE 3
		% CONT.:	54.	37.	4.	3.	99.	1.	1.	0.
5	COMP. ZO	ZONE ID:	ZONE 6	ZONE 13	COMP. ZON	ZONE 12	COMP. ZON	ZONE 13	ZONE 1	ZONE 3
		% CONT.:	29.	28.	28.	8.	99.	1.	0.	0.
6	COMP. ZO	ZONE ID:	COMP. ZON	ZONE 7	ZONE 17	ZONE 9	COMP. ZON	ZONE 7	ZONE 17	ZONE 9
		% CONT.:	70.	20.	5.	3.	99.	1.	0.	0.
7	ZONE 3	ZONE ID:	ZONE 3	ZONE 17	ZONE 5	ZONE 2 =	ZONE 3	ZONE 2 =	ZONE 17	ZONE 4
		% CONT.:	80.	18.	1.	1.	97.	3.	0.	0.
10	ZONE 27	ZONE ID:	ZONE 27	ZONE 19 =	ZONE 7	ZONE 26A	ZONE 27	ZONE 19 =	ZONE 4B	ZONE 5
		% CONT.:	72.	25.	2.	1.	80.	20.	0.	0.
11	CZ = ZON	ZONE ID:	CZ = ZONE	ZONE 10	ZONE 9	ZONE 5	CZ = ZONE	ZONE 2	ZONE 4	ZONE 5
		% CONT.:	99.	1.	0.	0.	100.	0.	0.	0.
12	ZONE 4 =	ZONE ID:	ZONE 31A	ZONE 31	ZONE 13	ZONE 17	ZONE 31A	ZONE 13	ZONE 17	ZONE 18
		% CONT.:	66.	34.	0.	0.	100.	0.	0.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 11	ZONE 6	ZONE 3	CZ 15	ZONE 3	ZONE 6	ZONE 7
		% CONT.:	100.	0.	0.	0.	100.	0.	0.	0.

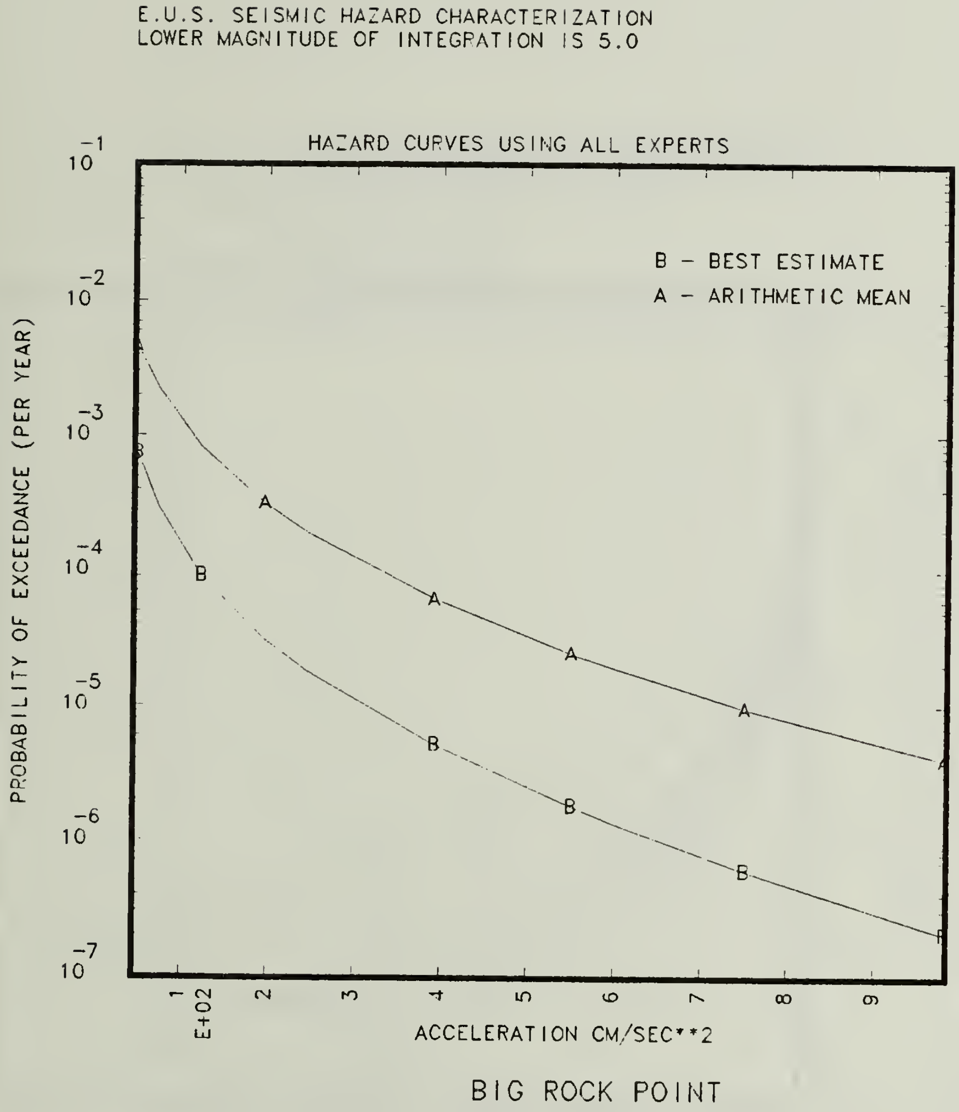


Figure 2.2.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Big Rock Point site.

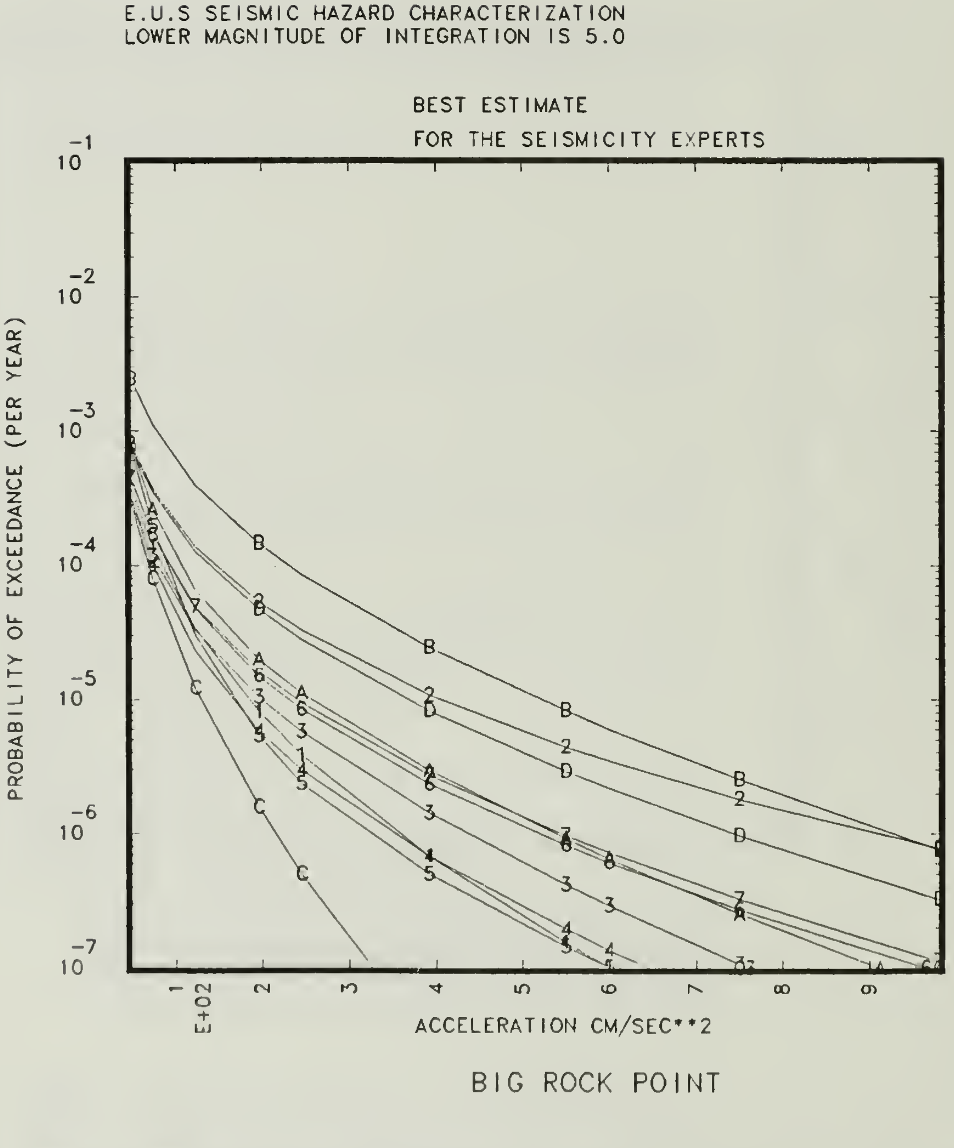


Figure 2.2.2 BEHCs per S-Expert combined over all G-Experts for the Big Rock Point site. Plot symbols given in Table 2.0.

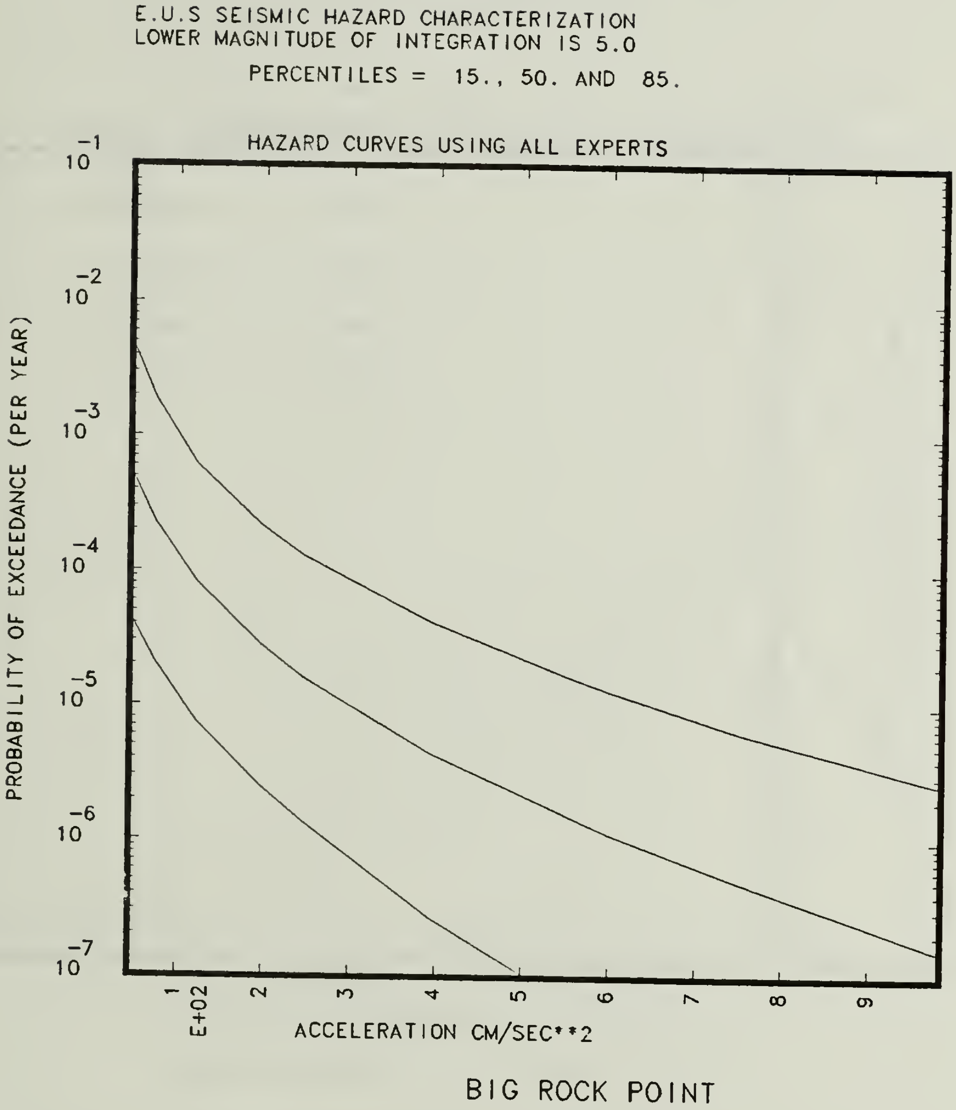
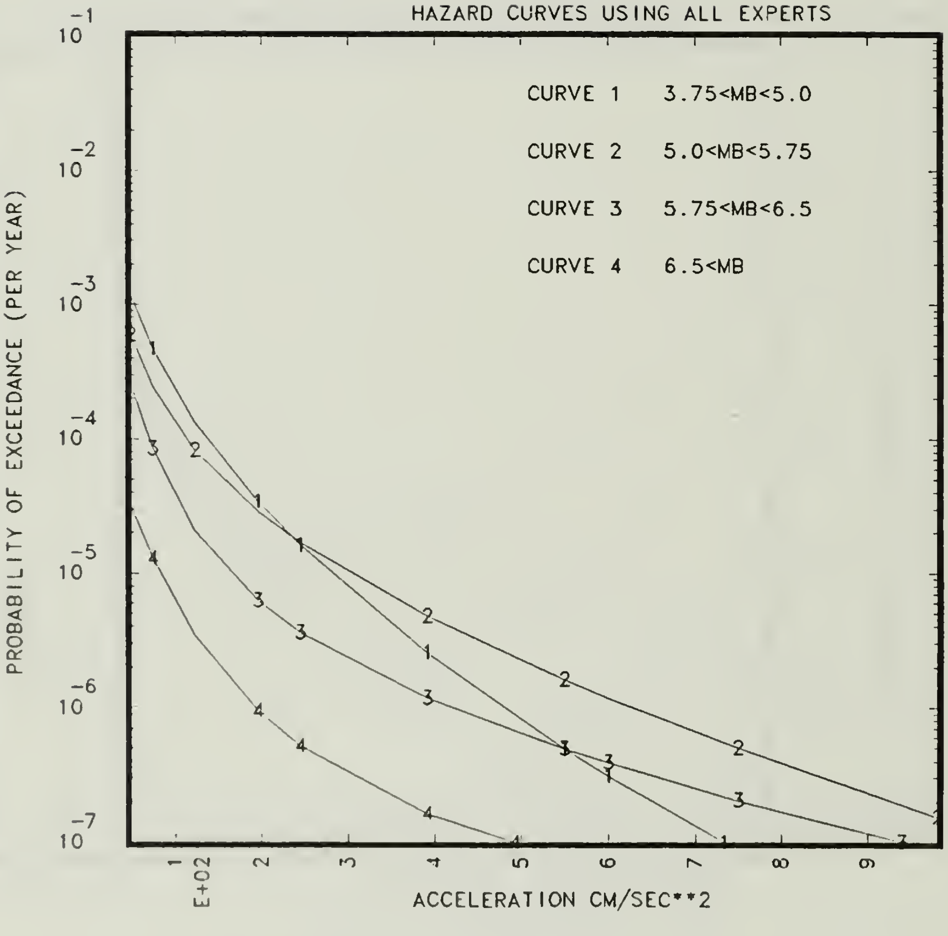


Figure 2.2.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Big Rock Point site.



BIG ROCK POINT

Figure 2.2.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Big Rock Point site.

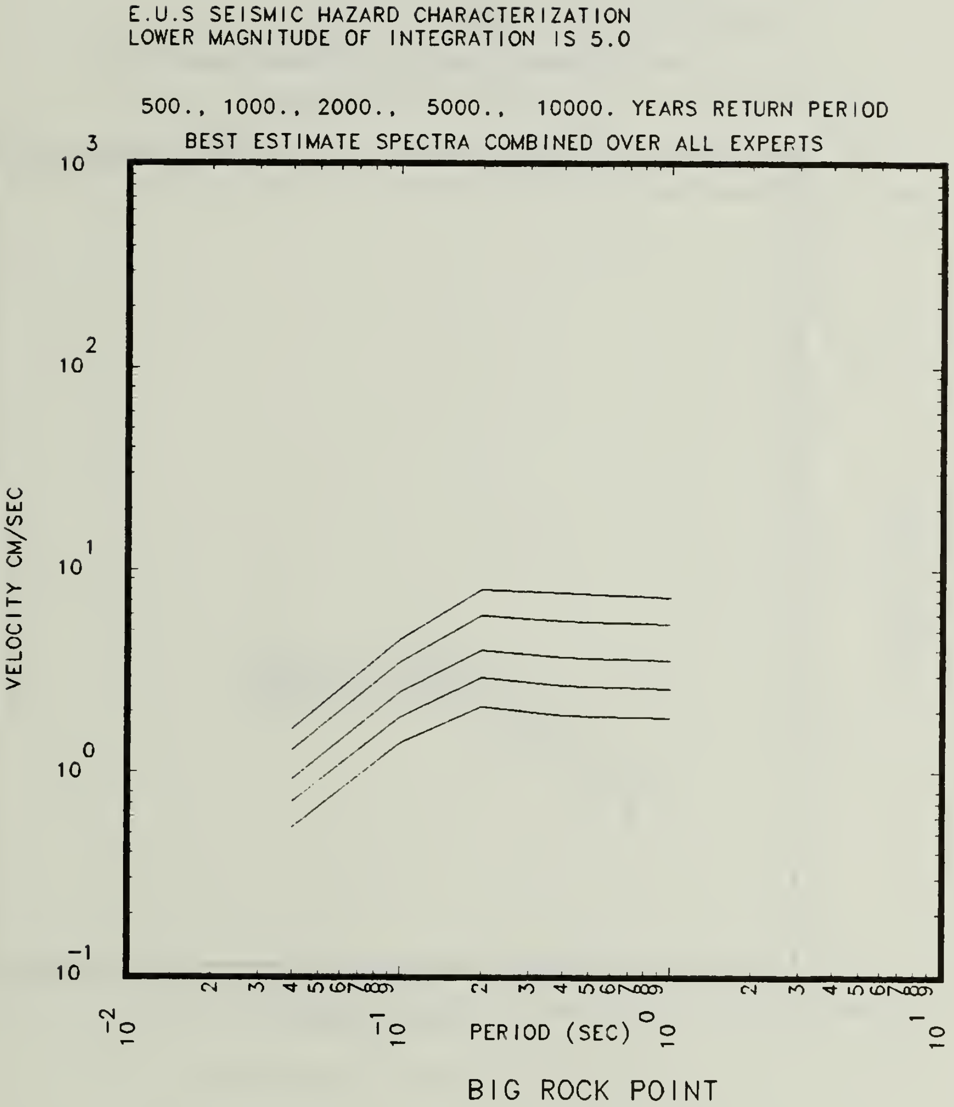


Figure 2.2.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Big Rock Point site.

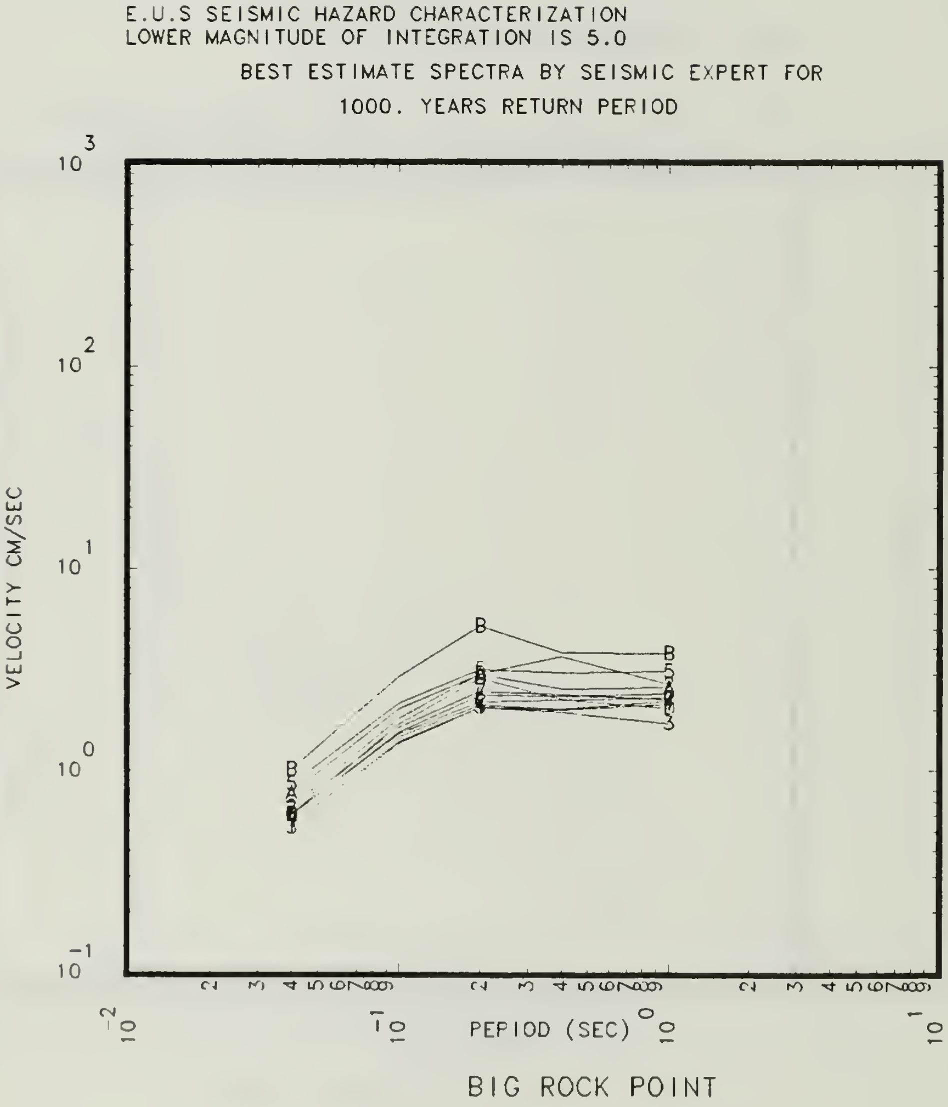


Figure 2.2.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Big Rock Point site. Plot symbols are given in Table 2.0.

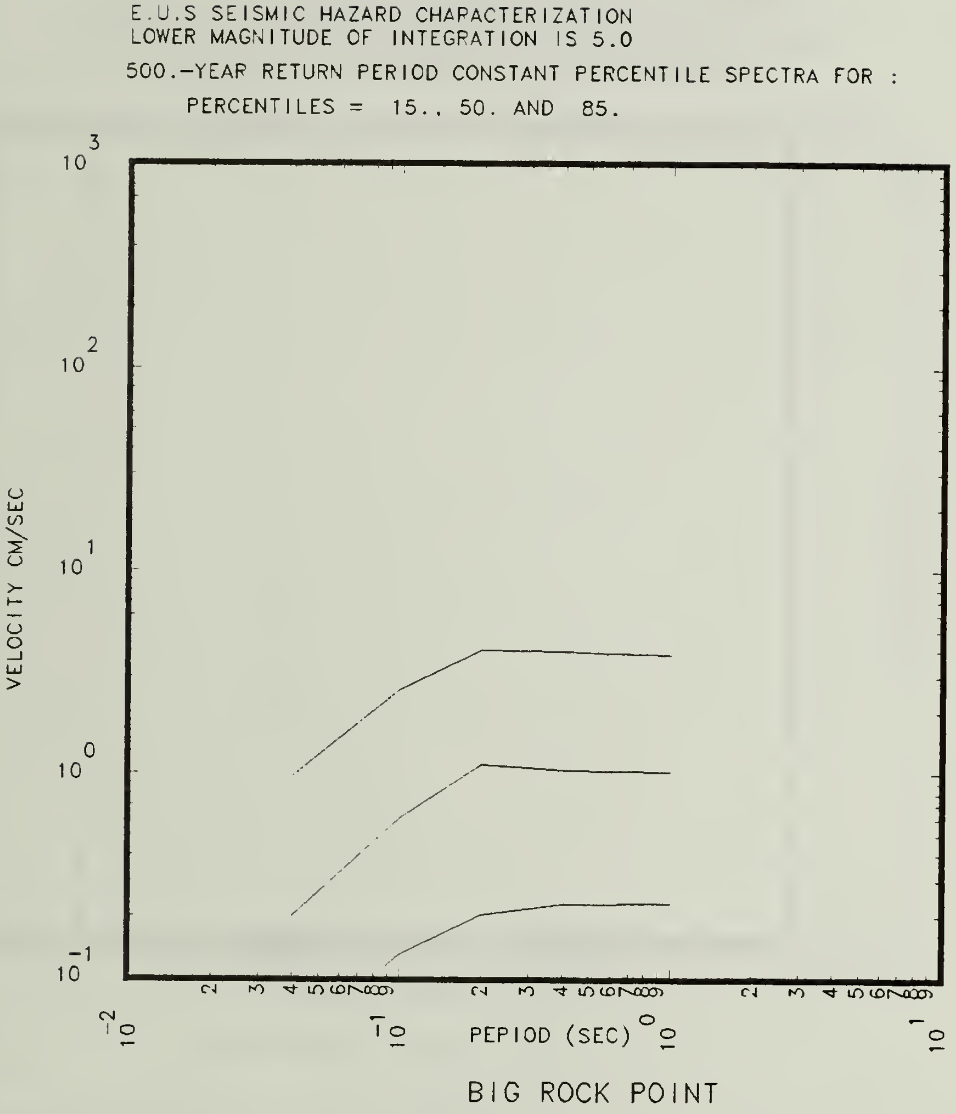


Figure 2.2.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Big Rock Point site.

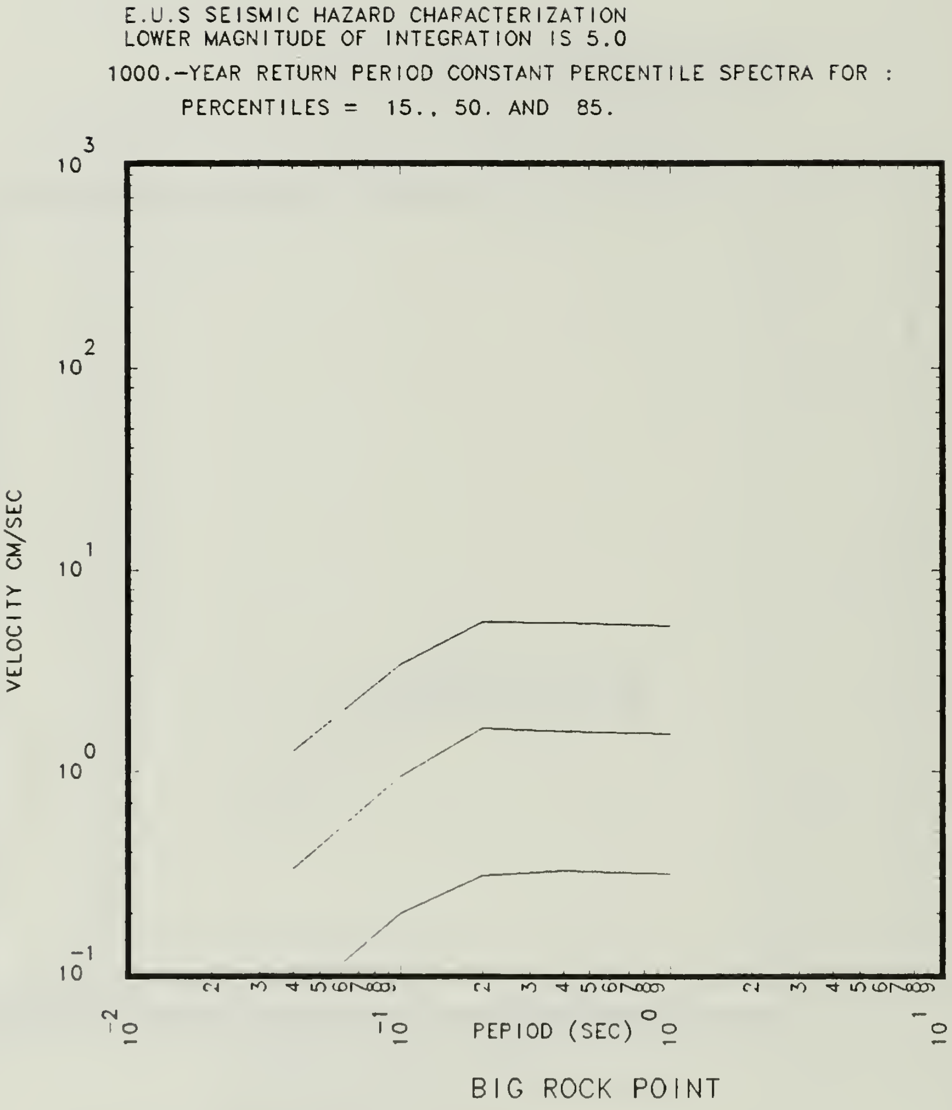
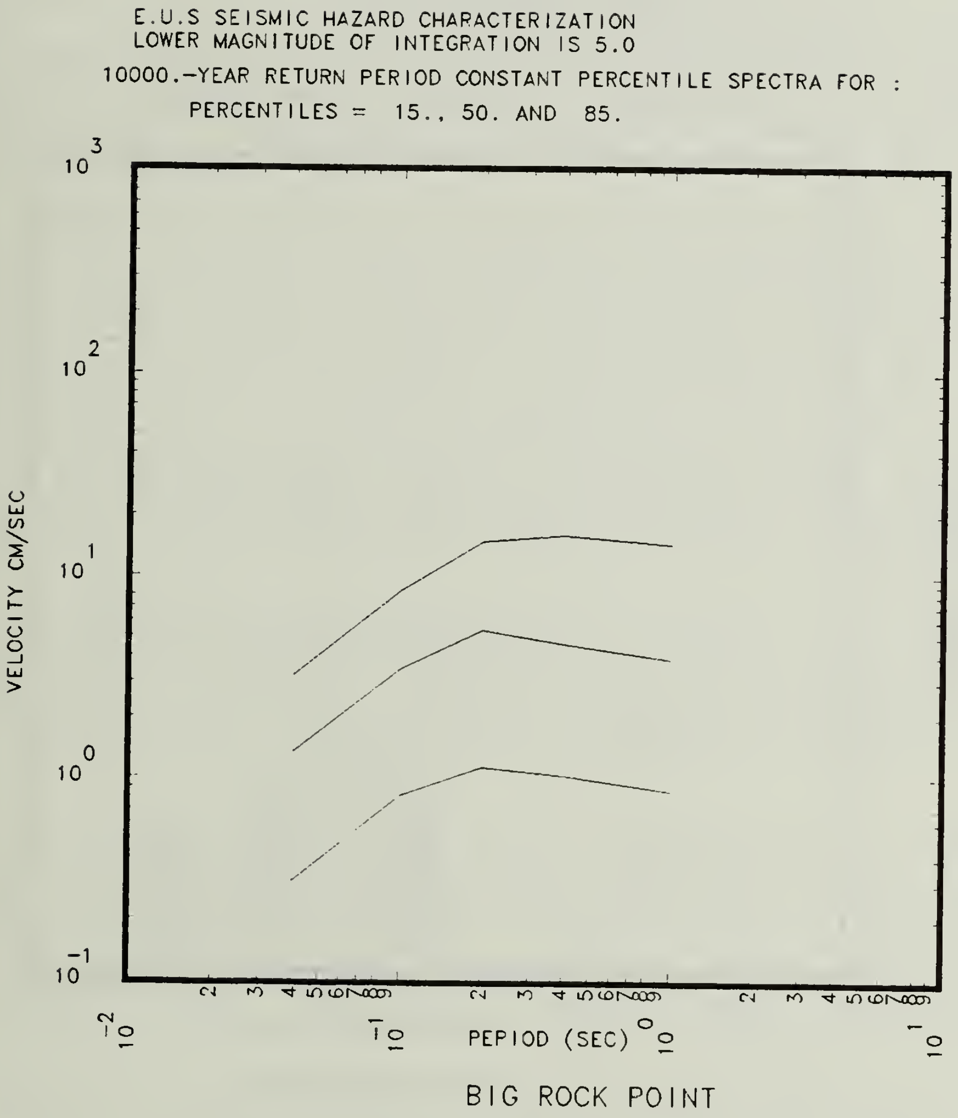


Figure 2.2.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Big Rock Point site.



igure 2.2.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Big Rock Point site.

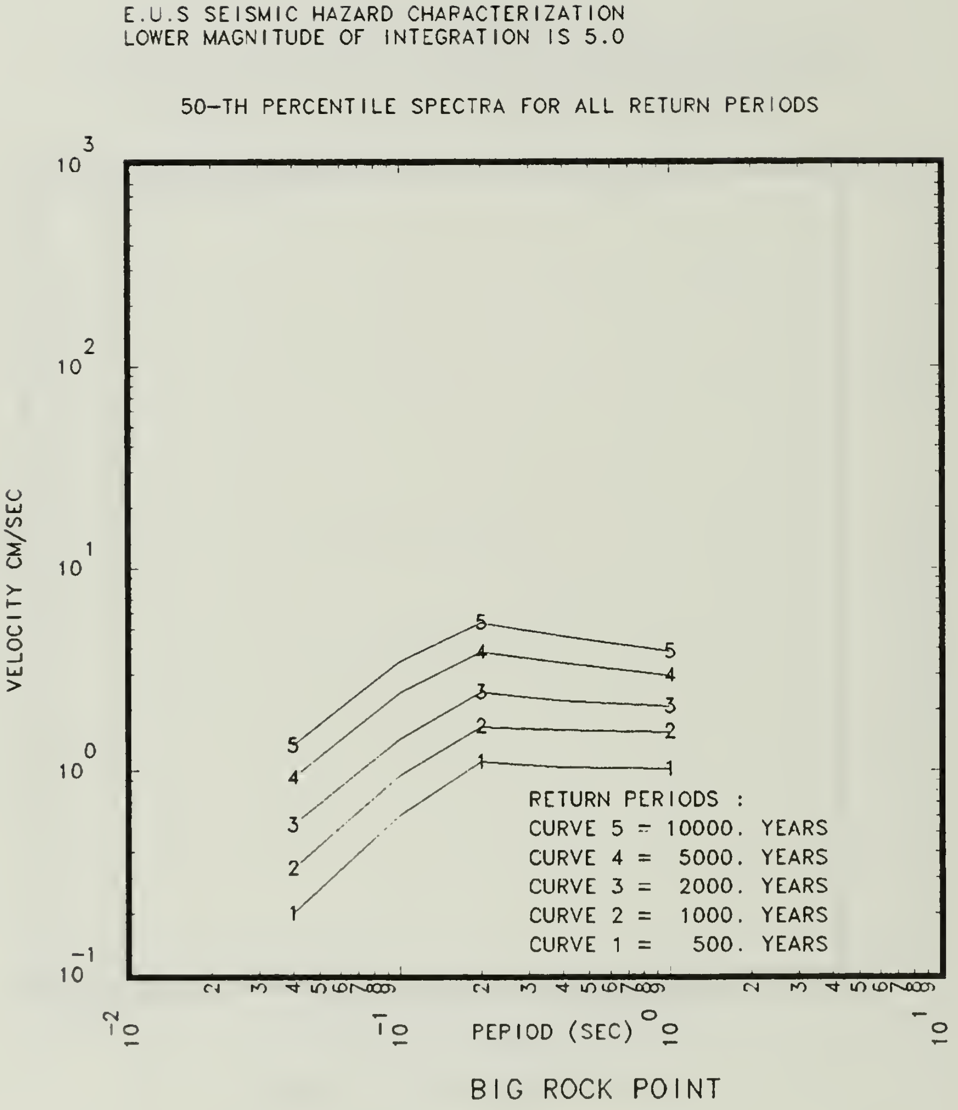


Figure 2.2.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Big Rock Point site.

2.3 BRAIDWOOD

The Braidwood site is a rock site and it is represented by the symbol "3" in Fig. 1.1. Table 2.3.1 and Figs. 2.3.1 through 2.3.10 give the basic results for the Braidwood site.

We see from Fig. 2.3.1 that the AMHC is significantly higher than the 85th percentile CPHC indicating the presence of high outliers in the set of simulated hazard curves. In addition, it can be seen from Fig. 2.3.3 that spread between the median and the 85th percentile CPHCs is larger than the spread between the 15th percentile and median CPHCs.

There are several reasons for wide spread between the various estimates of the seismic hazard at the Braidwood site shown in Fig. 2.3.1. First, there is a wide spread in opinion between the S-Experts about the zonation and seismicity of the region around the Braidwood site as can be seen from Fig. 2.3.2.

Secondly, examination of Table 2.3.1 reveals several interesting results about which zones are contributing most to the hazard the Braidwood site. In particular for most S-Experts somewhat distant zones are significant. This is more likely to occur if the site is a rock site such as Braidwood generally located in a region of relatively low seismicity but not too distant from zones which can have large earthquakes. To understand why this is the case it is helpful to recall that the BEHC are aggregated over the G-Experts (Per S-Expert) arithmetically so that a high outlier tends to dominate the results. G-Expert 5's ground motion model generally lead to BEHCs that are high outliers in the set of simulated hazard curves (relative to the other G-Experts' BEHCs per S-Expert) at the Braidwood site for several reasons:

(1) Most importantly, as discussed in Vol. 1 Section 3.5, for the same distance and magnitude the Model G16-A3 (G-Expert 5's choice for BE GM model) is higher by a factor of 2 relative to the other BE GM models for rock sites. A factor of 2 in PGA results is approximately a factor of 8-10 in probability of exceedance (see also Vol. VI, Section 3.2 for more details).

(2) It can be seen from Fig. 3.4 in Vol. 1 that G-Expert 5's BE PGA (GM model G16-A3) has significantly lower attenuation than the other models particularly at the later magnitudes. This coupled with the site correction factor for rock increases the contribution from distant zones which have larger earthquakes. For example, a simple calculation would show that for G-Expert 5's model, earthquakes of $m_b = 6.0$ have the same PGA at 100 km as $m_b = 5$ earthquakes at 20 km.

(3) G-Expert 5 set the random uncertainty (standard deviation on the natural log of the PGA) at 0.7 compared to the range of values (0.35 - 0.55) selected by the other G-Experts. Relative to results obtained with a value of 0.55, this larger uncertainty (0.7) leads to an increase in the G-Expert 5's BEHC by about a factor of 2 in probability of exceedance at lower g-values (0.2g) to over a factor of 3 at high g-levels (0.9g).

In summary, we typically expect at rock sites that the BEHC for G-Expert 5 for any S-Expert will be about a factor of 10 (in probability of exceedance) higher than the G-Experts' BEHCs if the hazard is primarily from zones near the site because of factors (1) and (3) noted above. This is illustrated in Fig. 2.3.11 where we plot the BEHCs per G-Expert for S-Expert 3's input. We see from Table 2.3.1 and the map in Appendix A for S-Expert 3 that the zones near the site contribute most to the BEHC. However, for some other S-Experts, in particular S-Experts 2, 5, 7 and 12, more distant zones with large earthquakes are more significant than the nearby zones. This is illustrated in Fig. 2.3.12 where we plot the BEHCs per G-Expert for S-Expert 2's input. The spread between G-Expert 5's BEHC and the BEHCs for the other G-Experts is even somewhat larger for S-Expert 5's input as shown in Fig. 2.3.13.

We also see from Fig. 2.3.4 that large earthquakes make the most significant contribution to the BEHC for PGA at the Braidwood site. We also see that including earthquakes in the magnitude range of 3.75 to 5 would only increase the BEHC slightly.

TABLE 2.3.1

MOST IMPORTANT ZONES PER S-EXPERT FOR BRAIDWOOD

SITE SOIL CATEGORY ROCK

S-XPT NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 19	ZONE ID:	ZONE 11	ZONE 19	ZONE 9	ZONE 10	ZONE 19	ZONE 9	ZONE 11	ZONE 10
		% CONT.:	29.	28.	27.	15.	50.	25.	21.	5.
2	ZONE 21	ZONE ID:	ZONE 18	ZONE 20	ZONE 21	COMP. ZON	ZONE 18	ZONE 21	COMP. ZON	ZONE 20
		% CONT.:	60.	18.	16.	4.	83.	11.	4.	2.
3	ZONE 15	ZONE ID:	ZONE 15	ZONE 12	ZONE 13	ZONE 16	ZONE 15	ZONE 16	ZONE 12	ZONE 13
		% CONT.:	33.	25.	17.	14.	68.	13.	9.	9.
4	COMP. ZO	ZONE ID:	ZONE 4	ZONE 6	ZONE 5	ZONE 3	ZONE 4	ZONE 6	ZONE 5	ZONE 13
		% CONT.:	50.	33.	13.	2.	48.	48.	3.	0.
5	COMP. ZO	ZONE ID:	ZONE 15	ZONE 14	ZONE 12	COMP. ZON	ZONE 15	COMP. ZON	ZONE 14	ZONE 12
		% CONT.:	69.	13.	13.	2.	98.	2.	1.	0.
6	ZONE 22	ZONE ID:	ZONE 17	ZONE 22	ZONE 18	ZONE 9	ZONE 17	ZONE 22	ZONE 18	ZONE 9
		% CONT.:	62.	25.	6.	6.	55.	40.	3.	1.
7	ZONE 34	ZONE ID:	ZONE 6	ZONE 34	ZONE 5	ZONE 2 =	ZONE 6	ZONE 34	ZONE 5	ZONE 2 =
		% CONT.:	77.	12.	9.	1.	87.	11.	1.	1.
10	ZONE 26A	ZONE ID:	ZONE 26A	ZONE 19 =	ZONE 12A	ZONE 13	ZONE 26A	ZONE 19 =	ZONE 12A	ZONE 13
		% CONT.:	51.	27.	14.	7.	77.	22.	1.	0.
11	CZ = ZON	ZONE ID:	ZONE 10	CZ = ZONE	ZONE 11	ZONE 9	ZONE 10	CZ = ZONE	ZONE 11	ZONE 9
		% CONT.:	64.	28.	7.	1.	59.	39.	2.	0.
12	ZONE 4 =	ZONE ID:	ZONE 13	ZONE 15	ZONE 14	ZONE 31A	ZONE 15	ZONE 14	ZONE 13	ZONE 5
		% CONT.:	44.	36.	18.	1.	92.	5.	3.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 5	ZONE 6	ZONE 4	CZ 15	ZONE 5	ZONE 6	ZONE 1
		% CONT.:	48.	34.	15.	1.	82.	17.	1.	0.

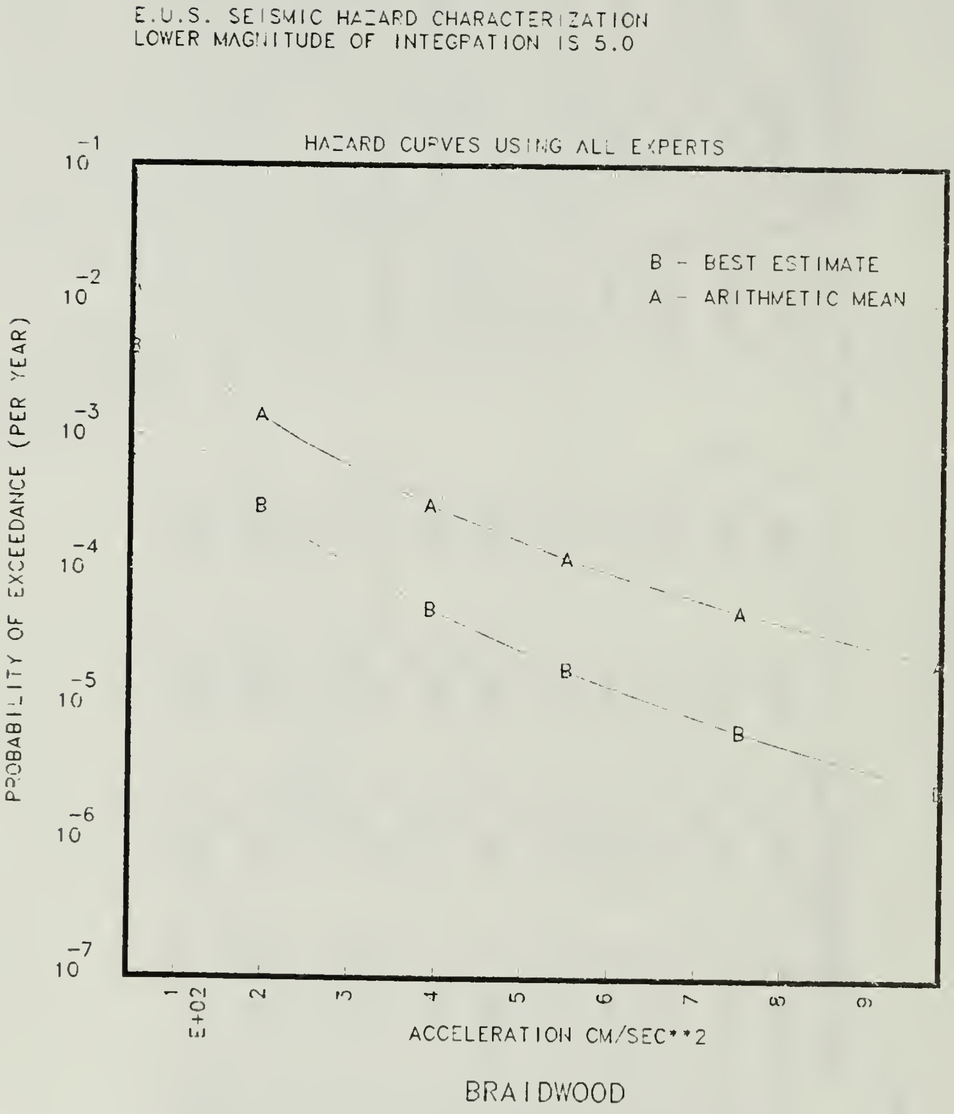


Figure 2.3.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Braidwood site.

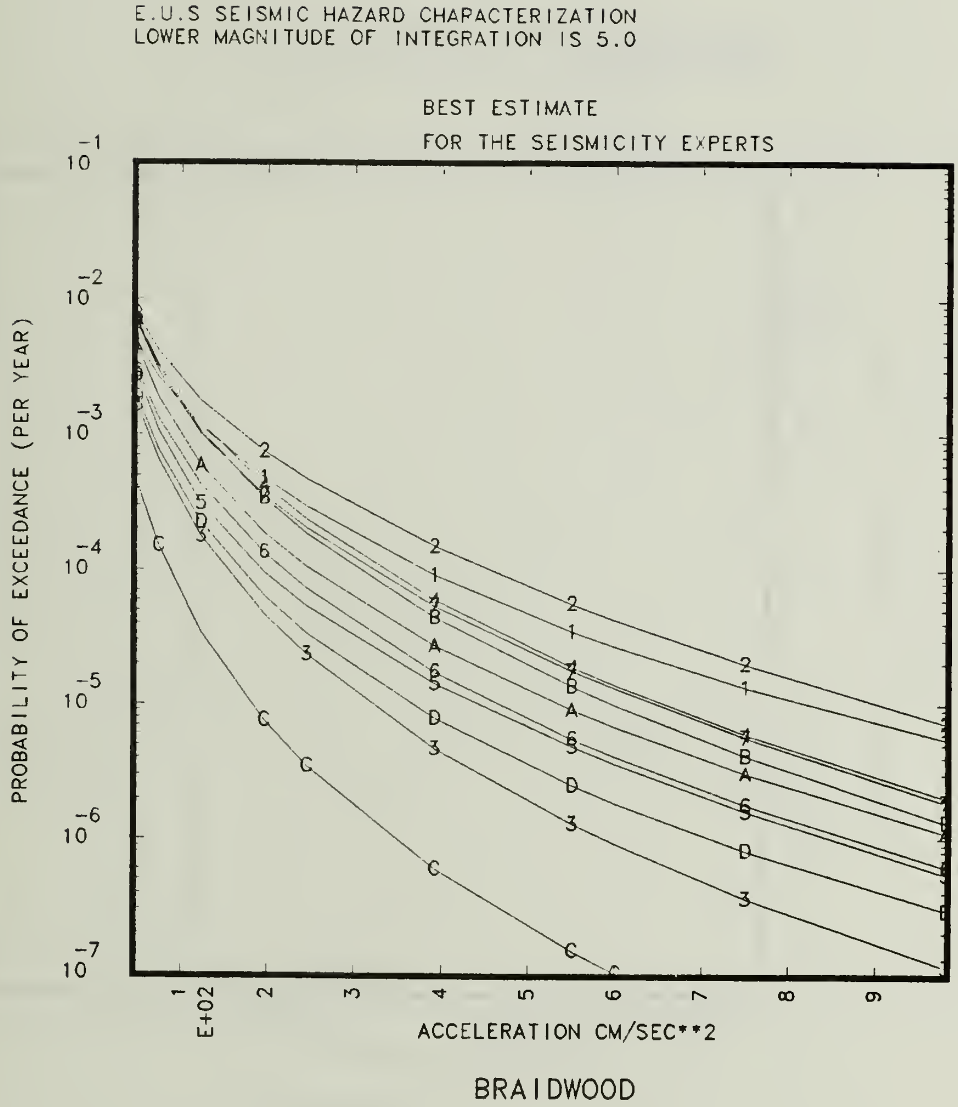


Figure 2.3.2 BEHCs per S-Expert combined over all G-Experts for the Braidwood site. Plot symbols given in Table 2.0.

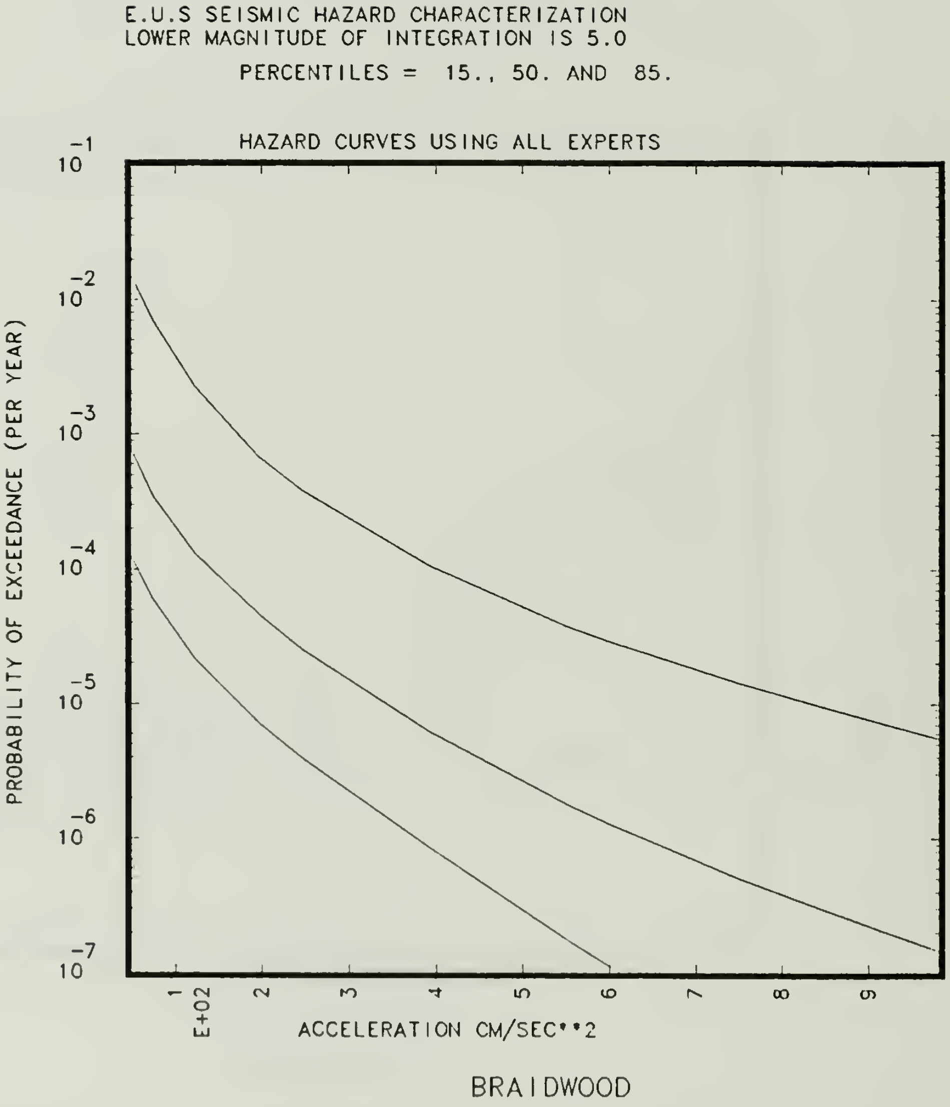


Figure 2.3.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Braidwood site.

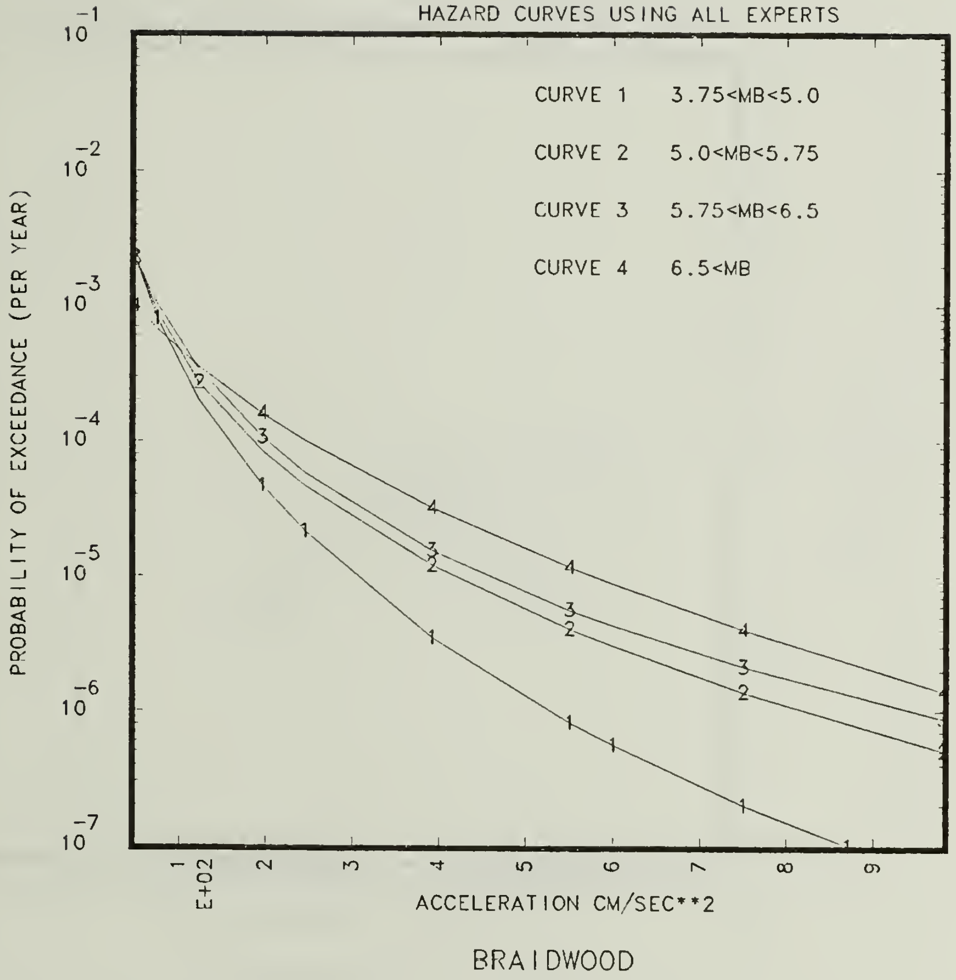


Figure 2.3.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Braidwood site.

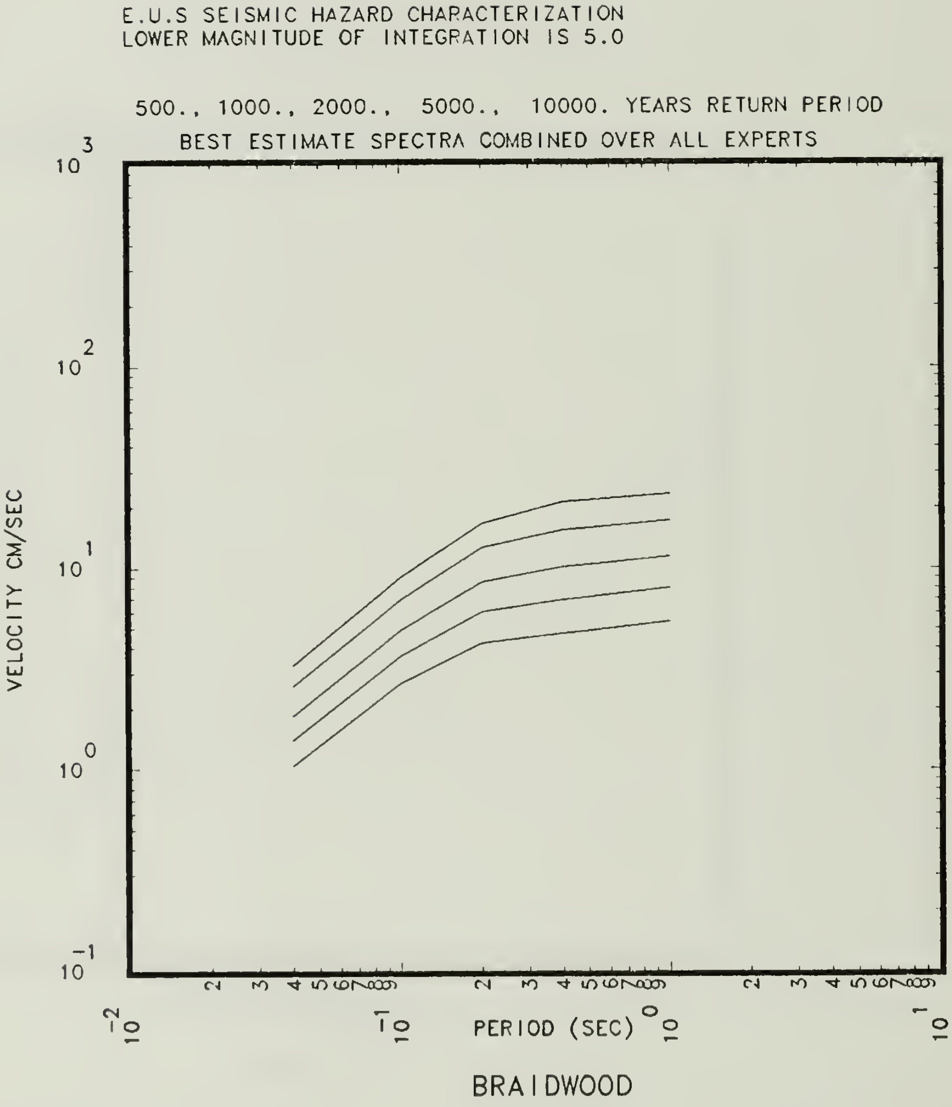
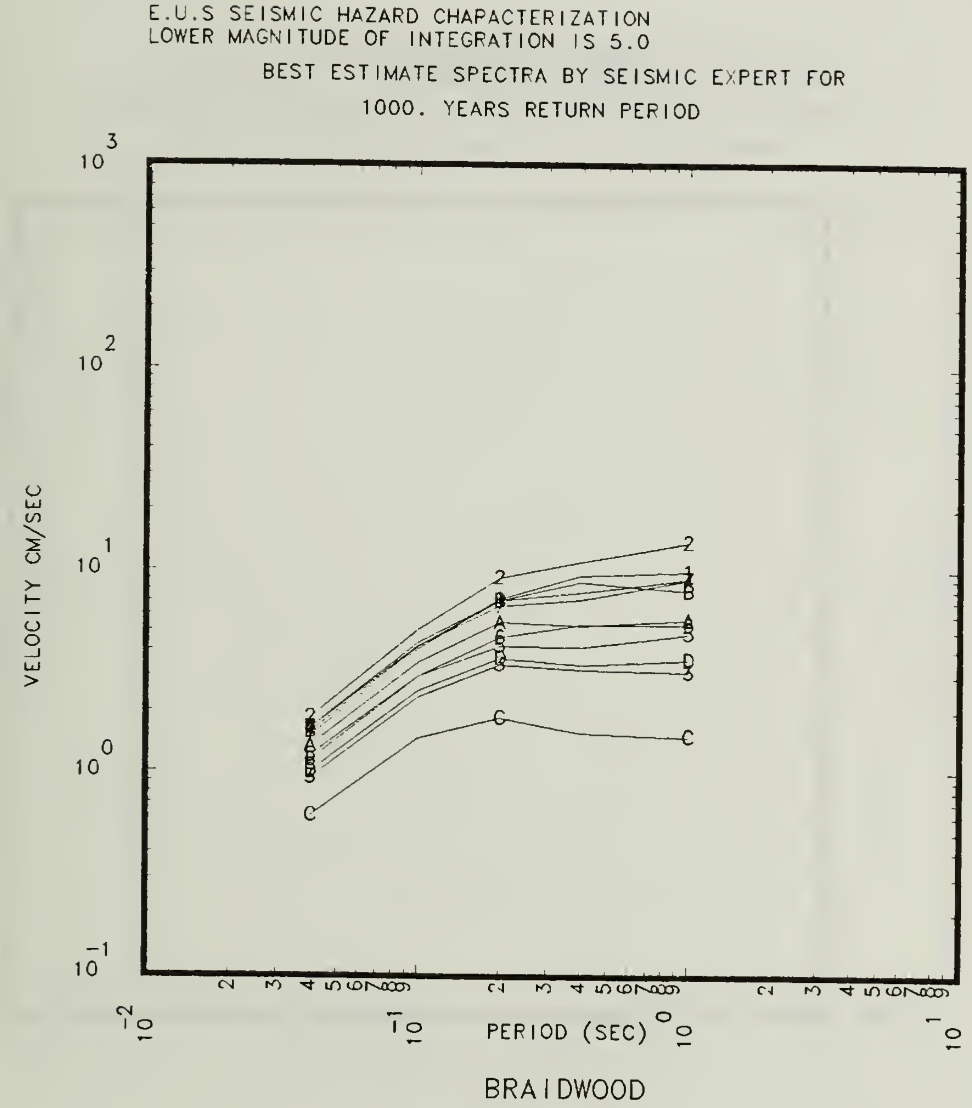


Figure 2.3.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Braidwood site.



igure 2.3.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Braidwood site. Plot symbols are given in Table 2.0.

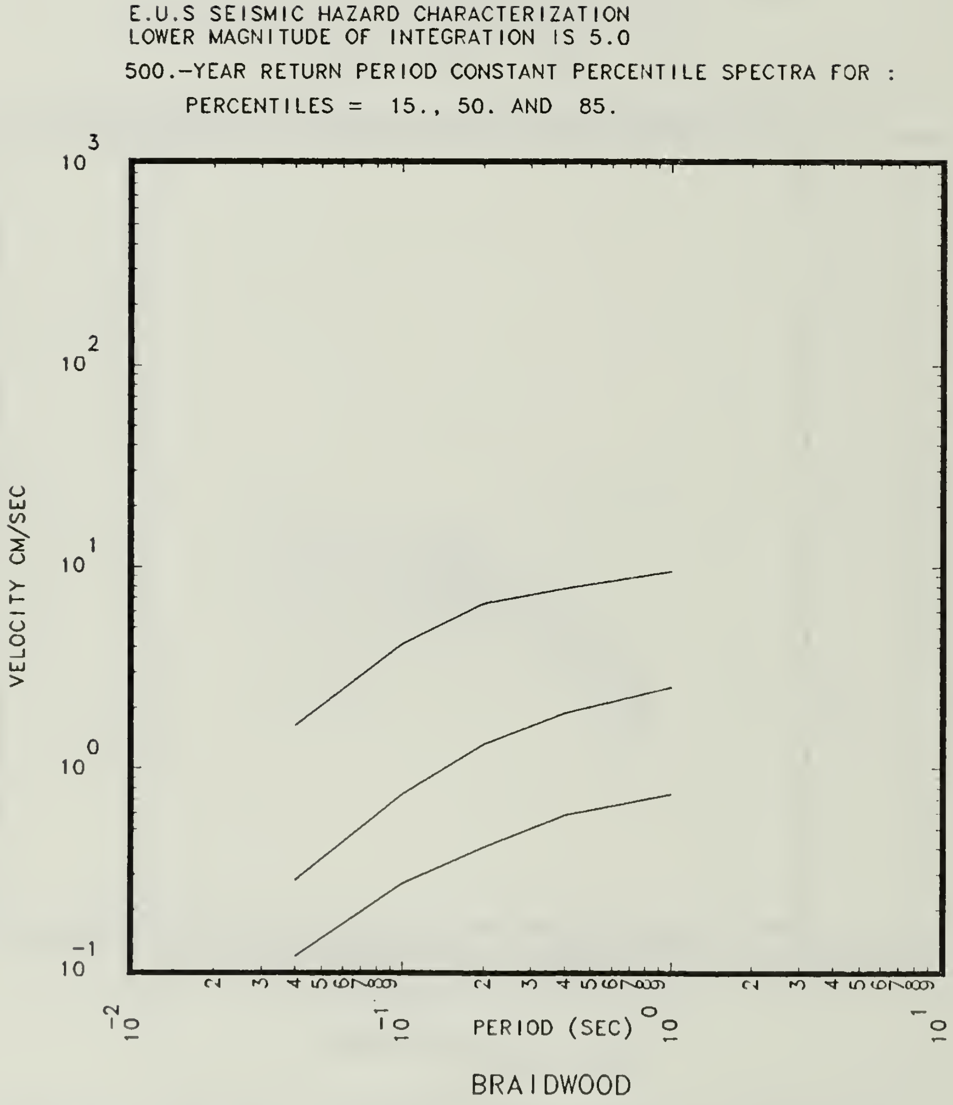
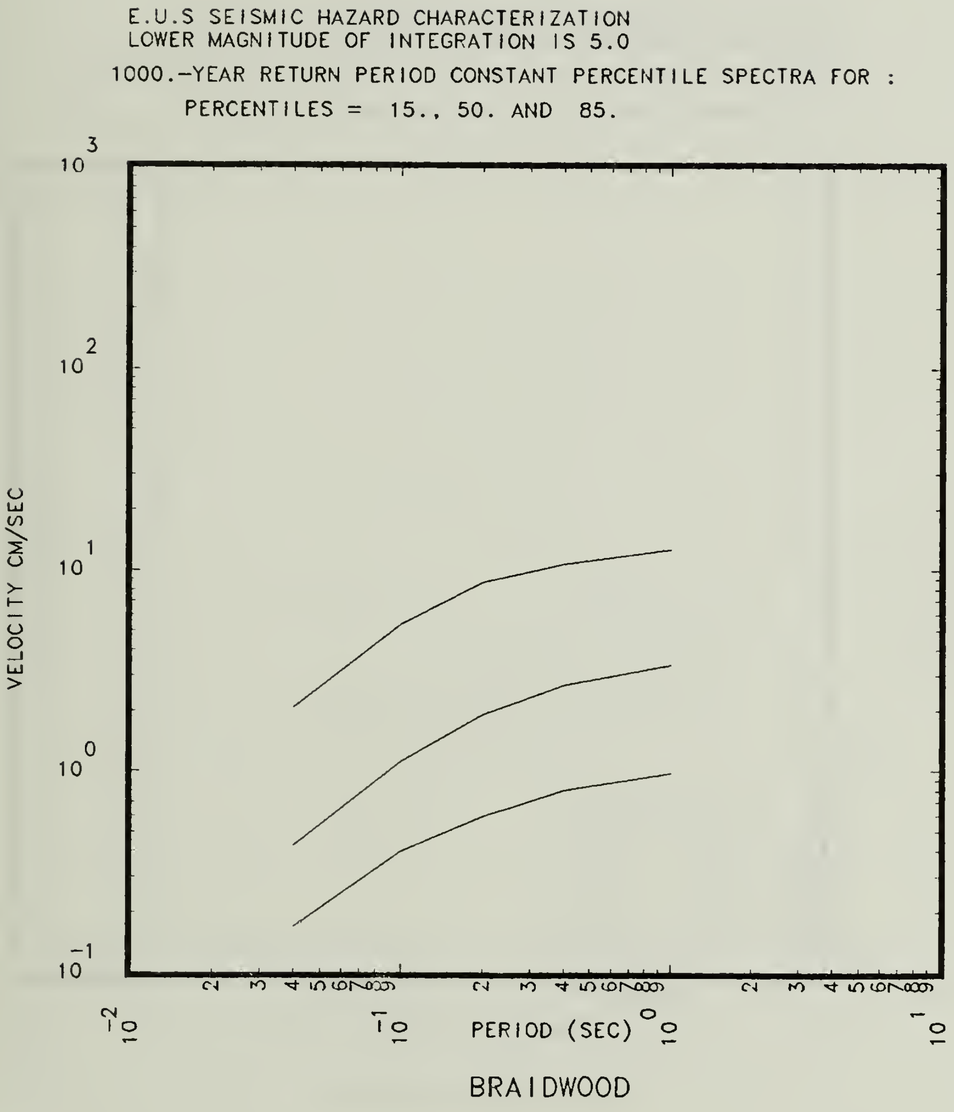


Figure 2.3.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Braidwood site.



igure 2.3.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Braidwood site.

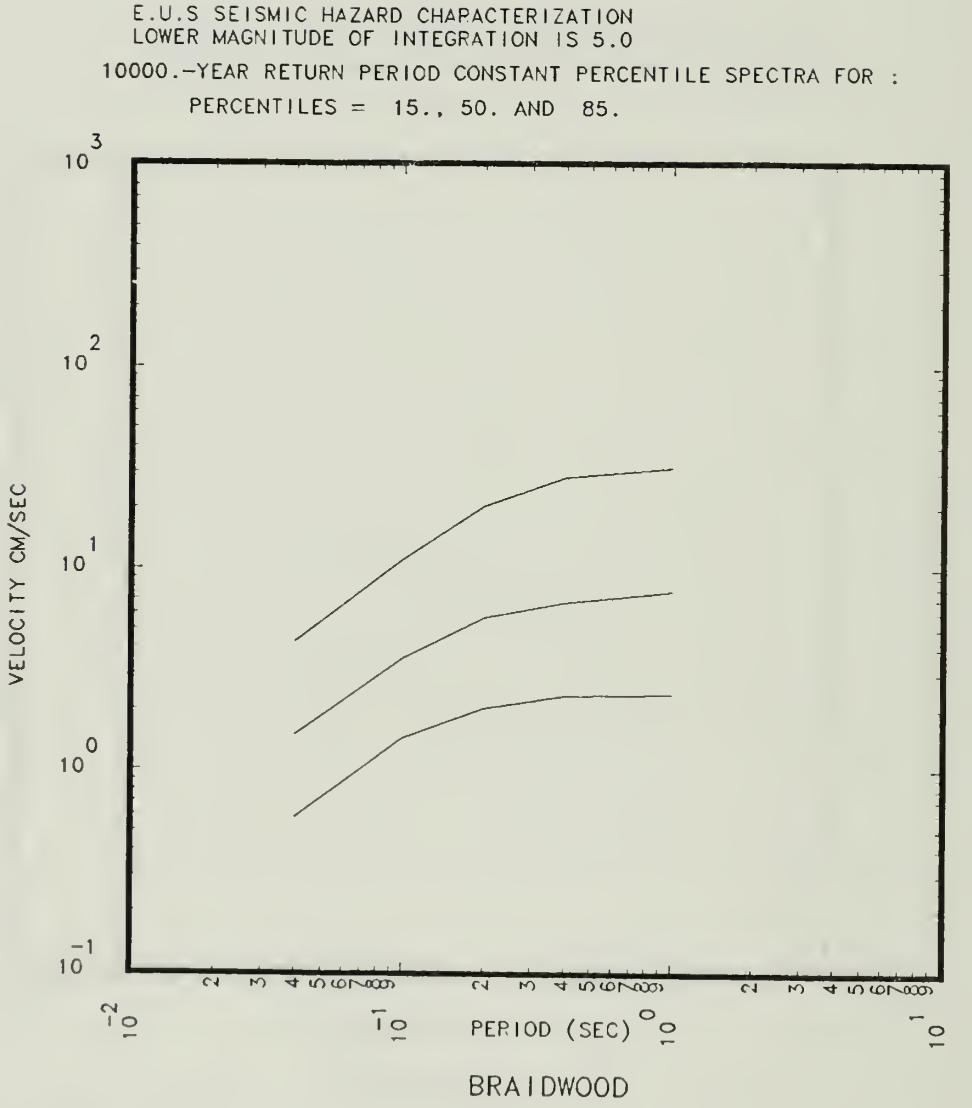


Figure 2.3.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Braidwood site.

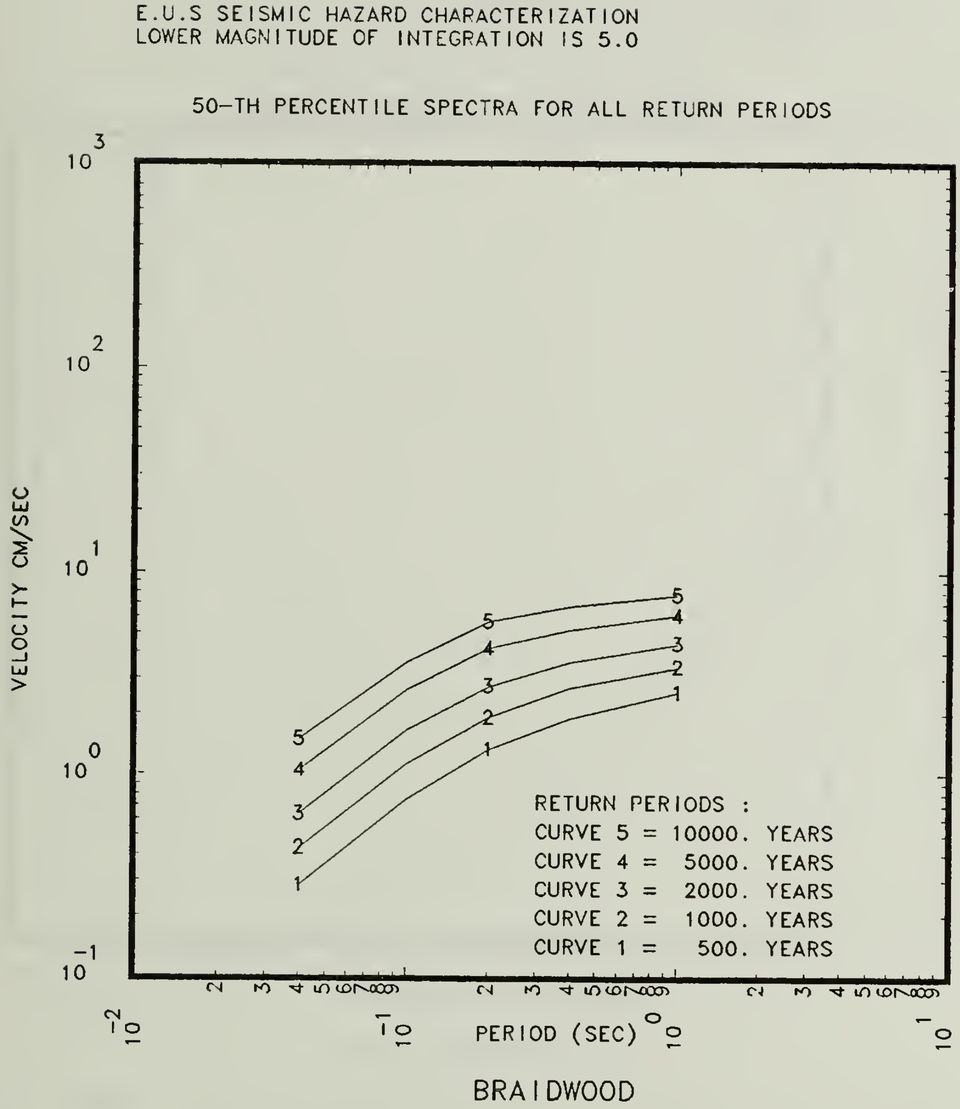


Figure 2.3.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Braidwood site.

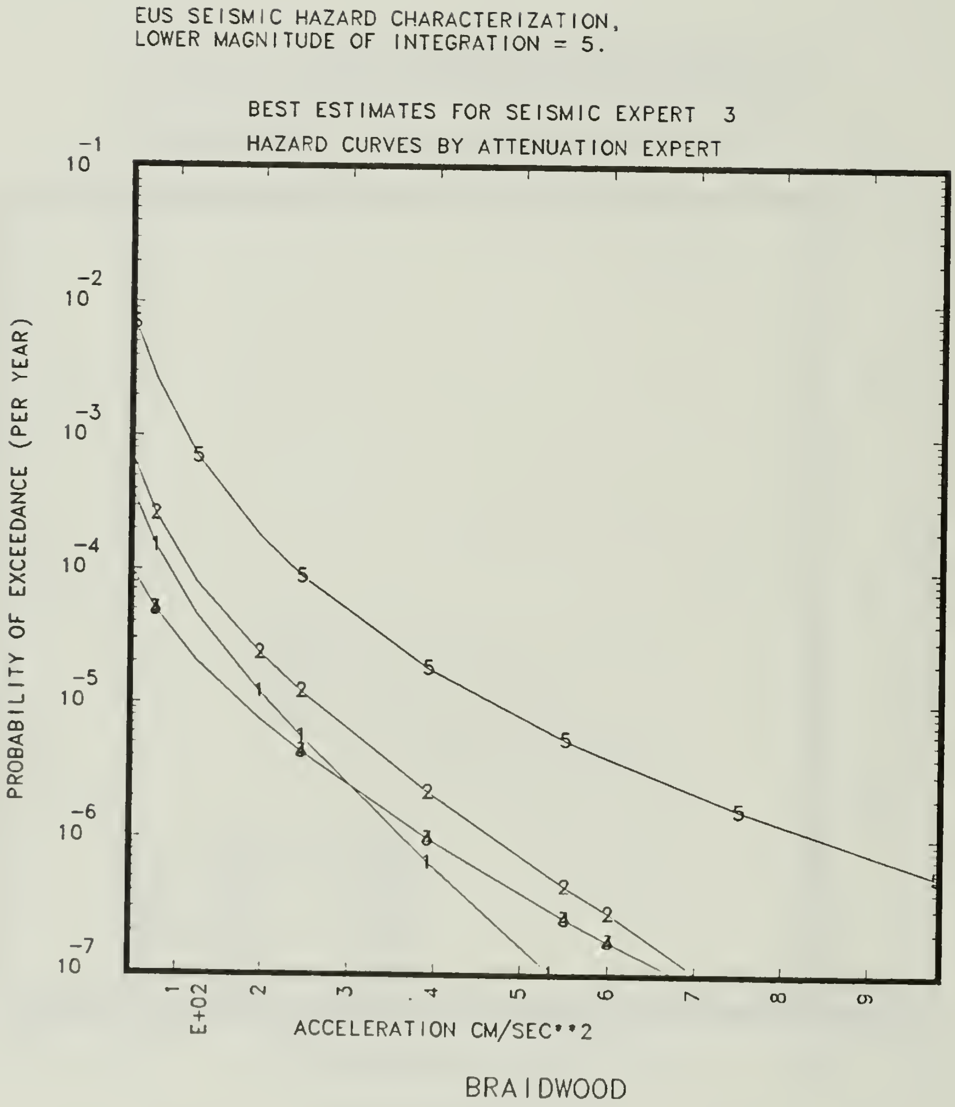


Figure 2.3.11 BEHCs per G-Expert for S-Expert 3's input. Illustrates the typical spread between the G-Experts' BEHCs for rock sites when the hazard is primarily from nearby zones.

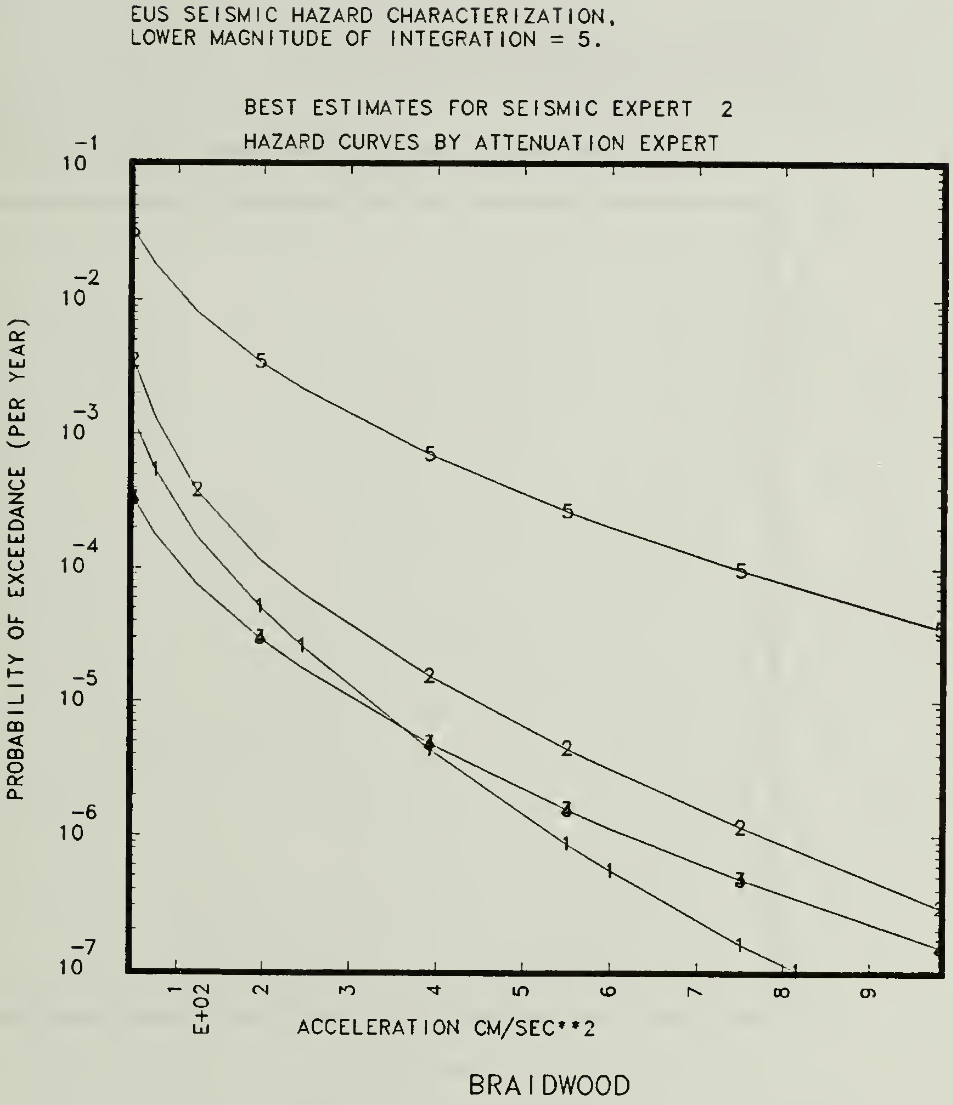


Figure 2.3.12 BEHCs per G-Expert for S-Expert 2's input for the Braidwood site. Illustrates the typical spread between the G-Experts' BEHCs for rock sites when the hazard is primarily from more distant zones with large earthquakes.

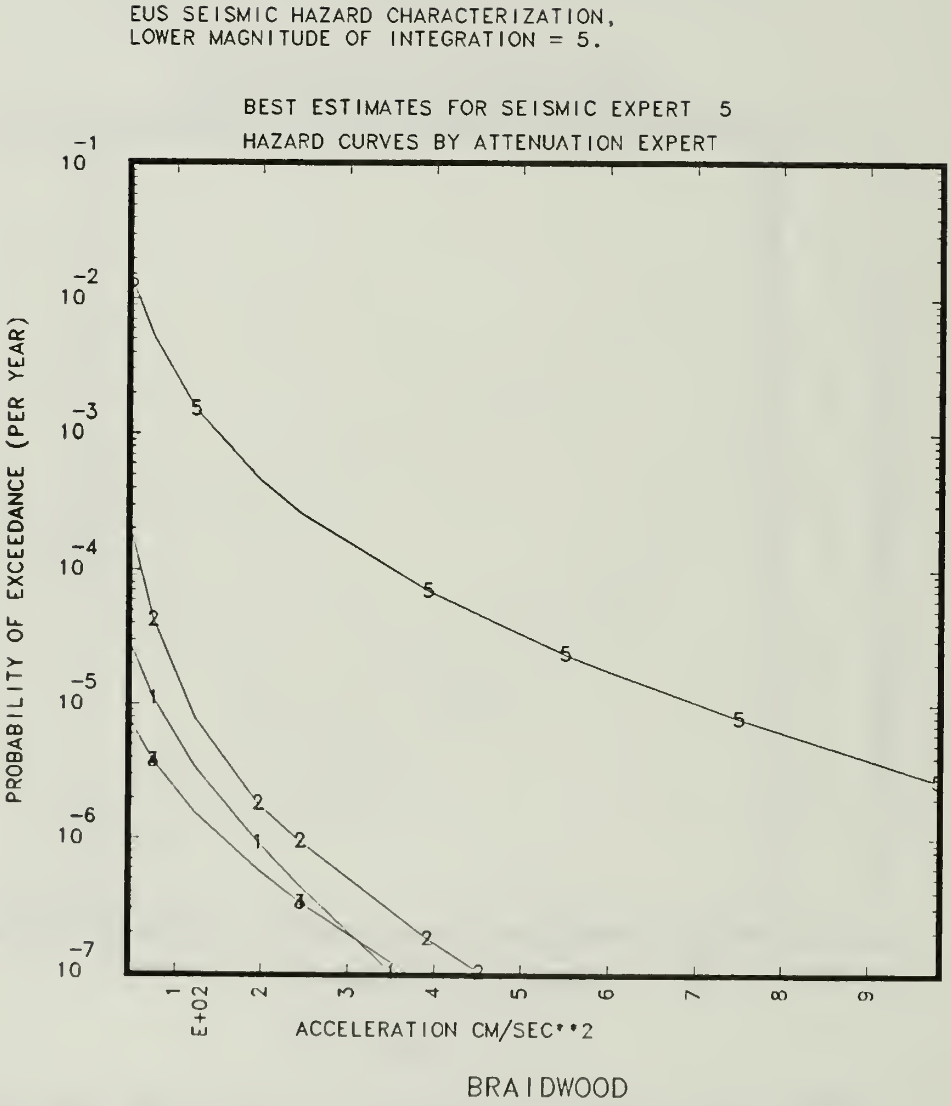


Figure 2.3.13 The BEHCs per G-Expert for S-Expert 5's zonation and seismicity parameters for the Braidwood site.

2.4 BYRON

The Byron site is a rock site (with some structures founded on soil) and it is represented by the symbol "4" in Fig. 1.1. Table 2.4.1 and Figs. 2.4.1 through 2.4.10 give the basic results for the Byron site.

As can be seen from Fig. 1.1 the Byron site is relatively near the Braidwood site hence the same discussion as given in Section 2.3 holds. However, as can be seen from Table 2.4.1 and the maps in Appendix B the Byron site is in S-Expert 4's zone 6. The Byron site is also "deeper" in S-Expert 2's zone 21 and S-Expert 3's zone 15 and S-Expert 6's zone 22. Thus more of the hazard is coming from zones near the site; hence as can be seen by comparing Fig. 2.3.4 to Fig. 2.4.4 that larger earthquakes are somewhat less important and smaller earthquakes relatively more important at the Byron site than at the Braidwood site. However, the hazard at the Byron site would only be slightly increased if earthquakes in the range of 3.75 to 5 were included.

TABLE 2.4.1

MOST IMPORTANT ZONES PER S-EXPERT FOR BYRON 1 & 2

SITE SOIL CATEGORY ROCK

S-XPT NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 19	ZONE ID:	ZONE 9	ZONE 11	ZONE 19	ZONE 10	ZONE 19	ZONE 9	ZONE 11	ZONE 10
		% CONT.:	30.	27.	26.	14.	55.	24.	17.	3.
2	ZONE 21	ZONE ID:	ZONE 18	ZONE 21	ZONE 20	COMP. ZON	ZONE 18	ZONE 21	COMP. ZON	ZONE 20
		% CONT.:	58.	28.	9.	4.	68.	29.	3.	0.
3	ZONE 15	ZONE ID:	ZONE 15	ZONE 12	ZONE 13	ZONE 11	ZONE 15	ZONE 13	ZONE 12	COMP. ZON
		% CONT.:	61.	18.	14.	3.	93.	4.	2.	0.
4	ZONE 6	ZONE ID:	ZONE 6	ZONE 4	ZONE 5	ZONE 3	ZONE 6	ZONE 4	ZONE 5	ZONE 3
		% CONT.:	61.	32.	5.	1.	82.	17.	0.	0.
5	COMP. ZO	ZONE ID:	ZONE 15	ZONE 14	ZONE 12	COMP. ZON	ZONE 15	COMP. ZON	ZONE 14	ZONE 12
		% CONT.:	78.	9.	8.	3.	97.	3.	0.	0.
6	ZONE 22	ZONE ID:	ZONE 17	ZONE 22	ZONE 18	ZONE 9	ZONE 22	ZONE 17	ZONE 18	COMP. ZON
		% CONT.:	46.	41.	7.	3.	71.	25.	4.	0.
7	ZONE 34	ZONE ID:	ZONE 6	ZONE 34	ZONE 5	ZONE 2 =	ZONE 6	ZONE 34	ZONE 2 =	ZONE 5
		% CONT.:	75.	18.	5.	1.	80.	19.	0.	0.
10	ZONE 26A	ZONE ID:	ZONE 26A	ZONE 19 =	ZONE 12A	ZONE 13	ZONE 26A	ZONE 19 =	ZONE 12A	ZONE 5
		% CONT.:	54.	31.	10.	4.	79.	20.	0.	0.
11	CZ = ZON	ZONE ID:	CZ = ZONE	ZONE 10	ZONE 11	ZONE 9	CZ = ZONE	ZONE 10	ZONE 11	ZONE 5
		% CONT.:	47.	45.	7.	0.	75.	23.	1.	0.
12	ZONE 4 =	ZONE ID:	ZONE 15	ZONE 13	ZONE 14	ZONE 31A	ZONE 15	ZONE 14	ZONE 13	ZONE 5
		% CONT.:	44.	35.	18.	2.	97.	3.	1.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 5	ZONE 6	ZONE 4	CZ 15	ZONE 5	ZONE 6	ZONE 1
		% CONT.:	56.	36.	7.	1.	85.	15.	0.	0.

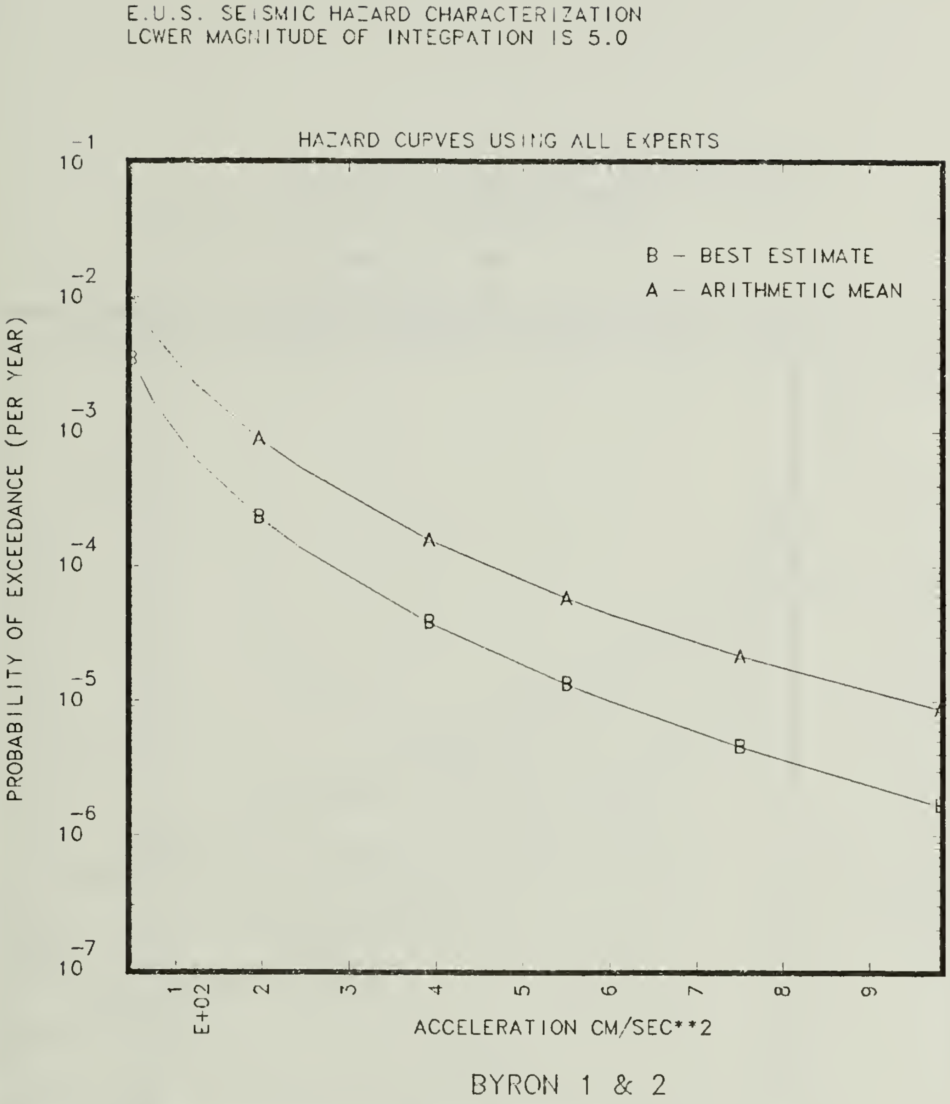


Figure 2.4.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Byron site.

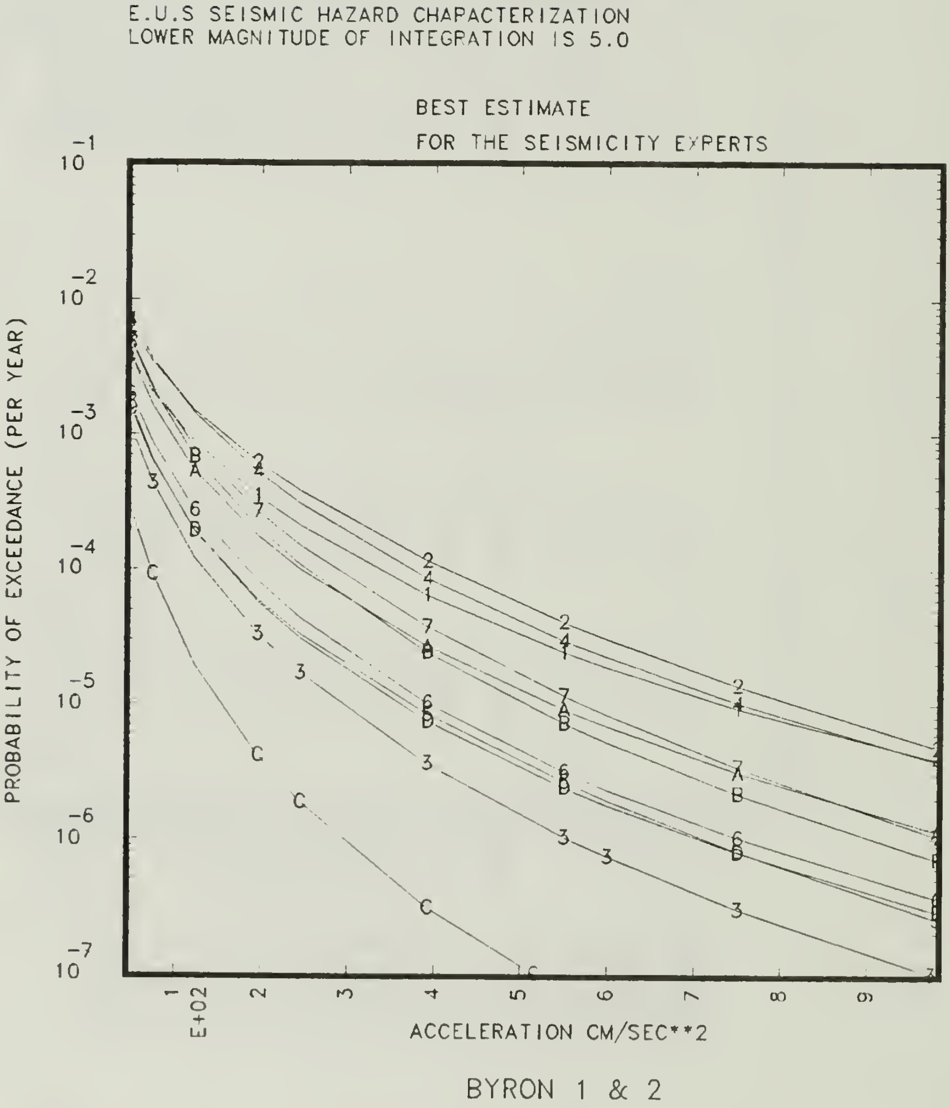
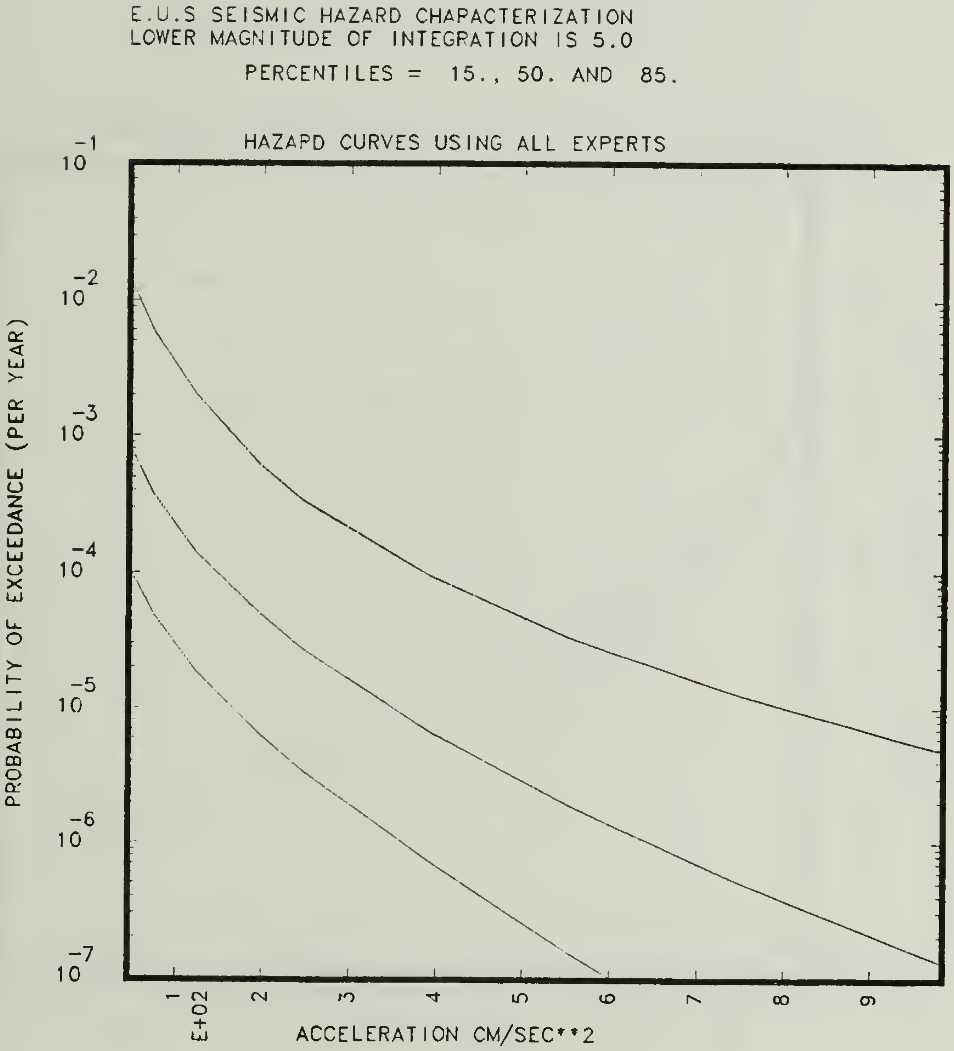


Figure 2.4.2 BEHCs per S-Expert combined over all G-Experts for the Byron site. Plot symbols given in Table 2.0.



BYRON 1 & 2

Figure 2.4.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Byron site.

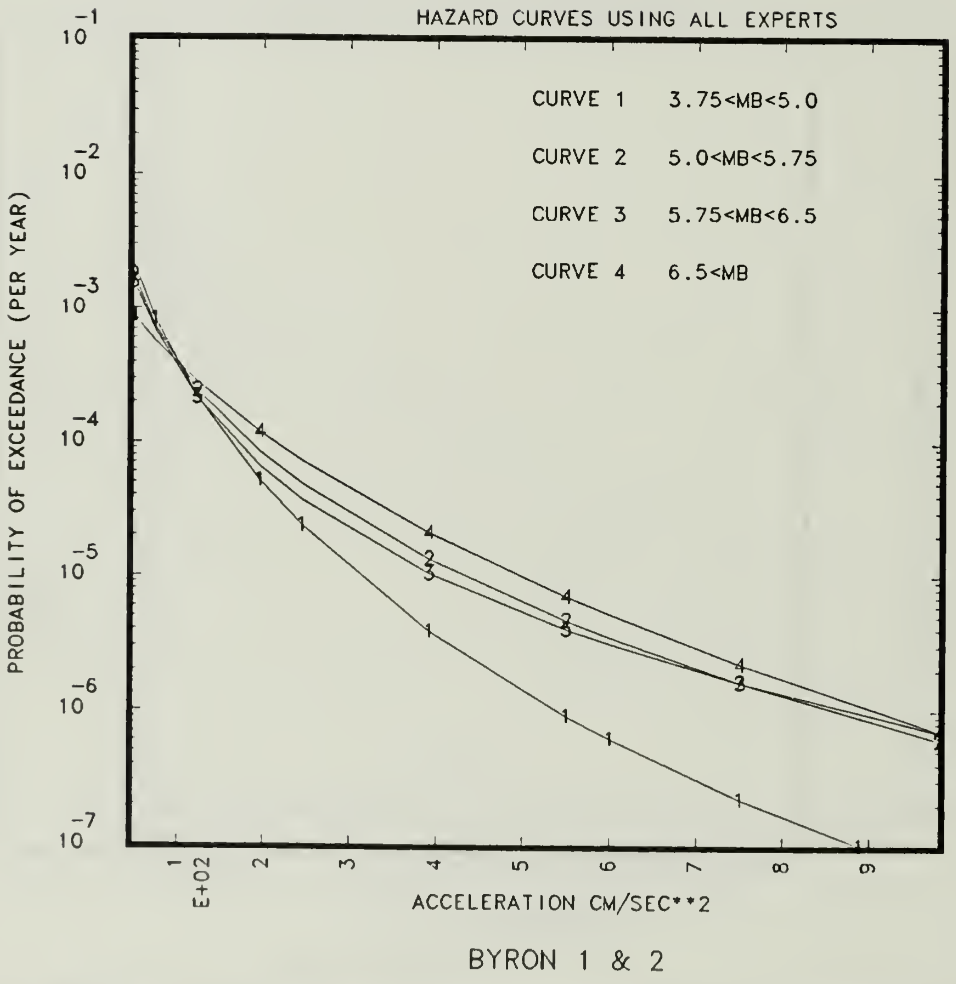


Figure 2.4.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Byron site.

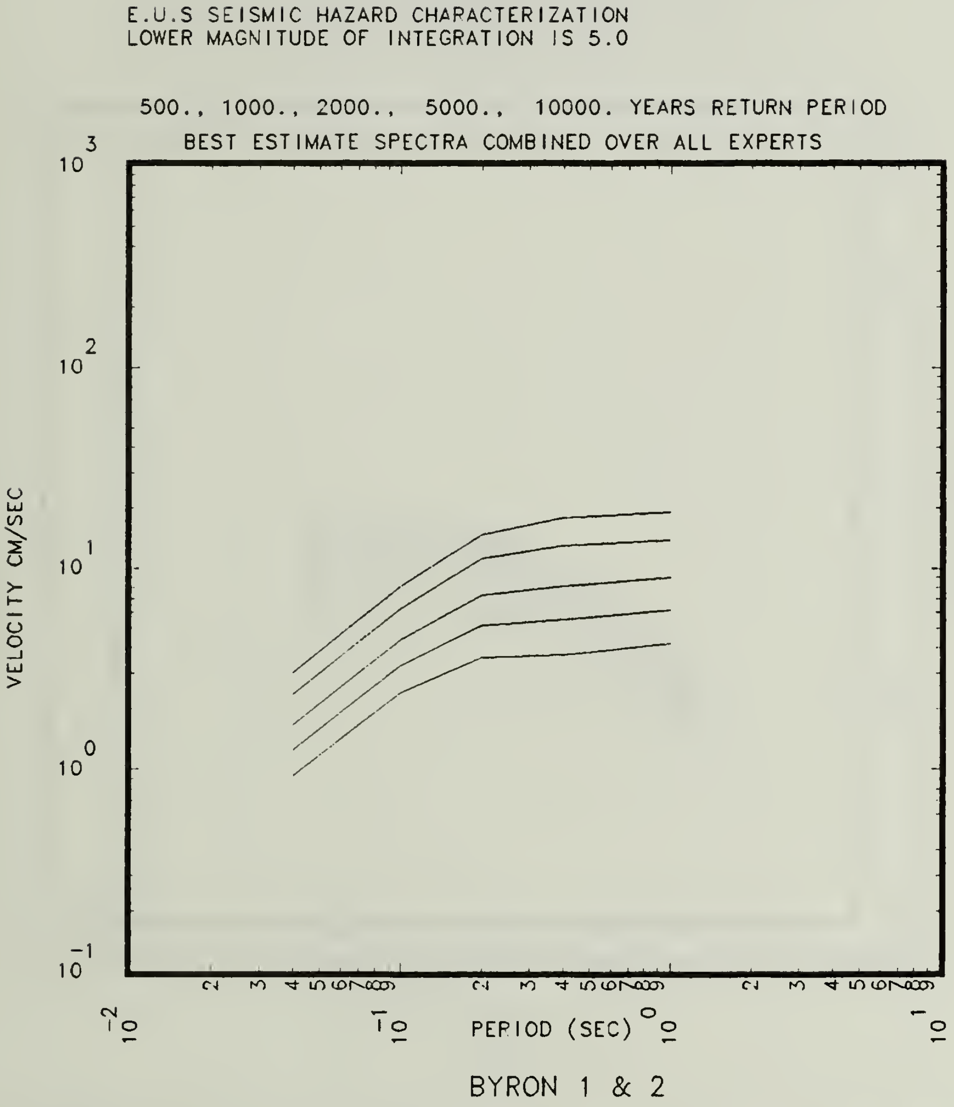


Figure 2.4.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Byron site.

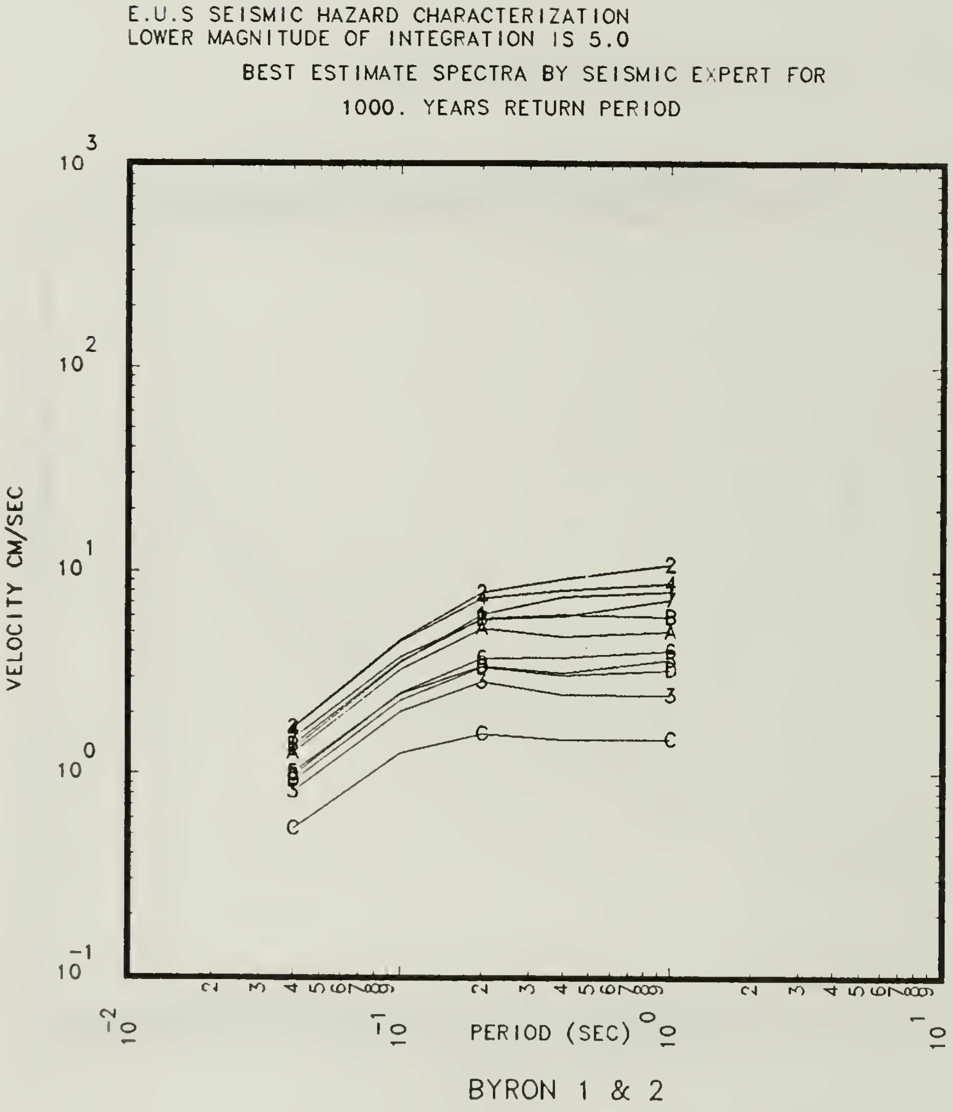


Figure 2.4.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Byron site. Plot symbols are given in Table 2.0.

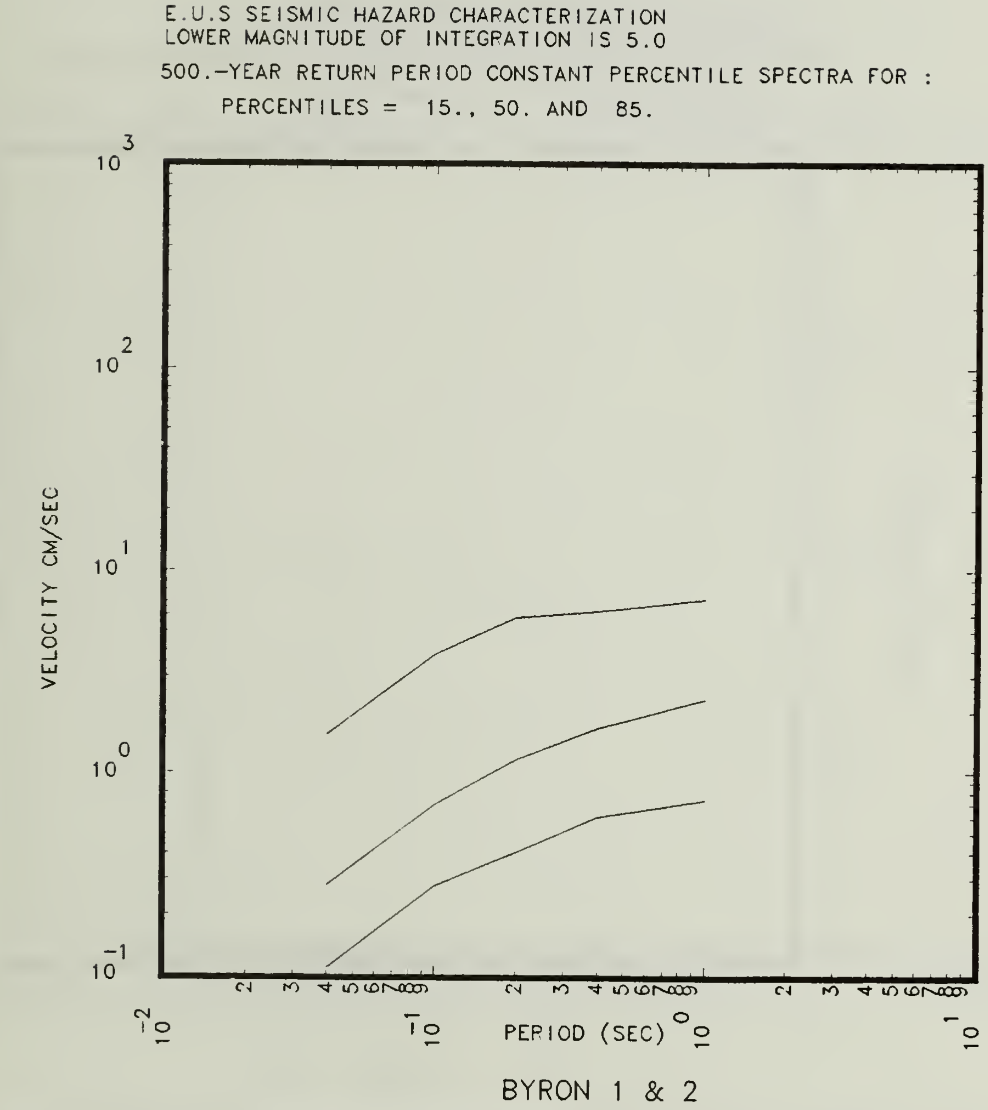


Figure 2.4.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Byron site.

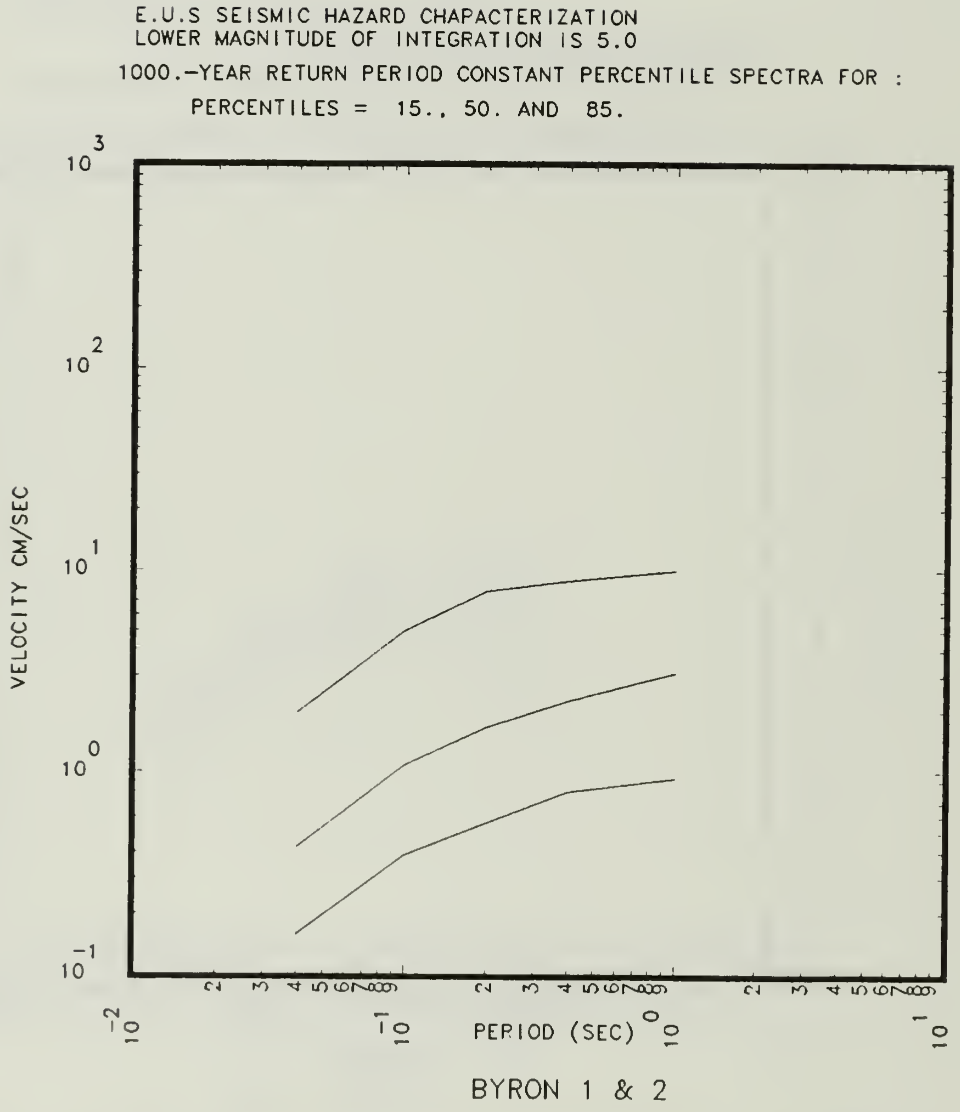


Figure 2.4.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Byron site.

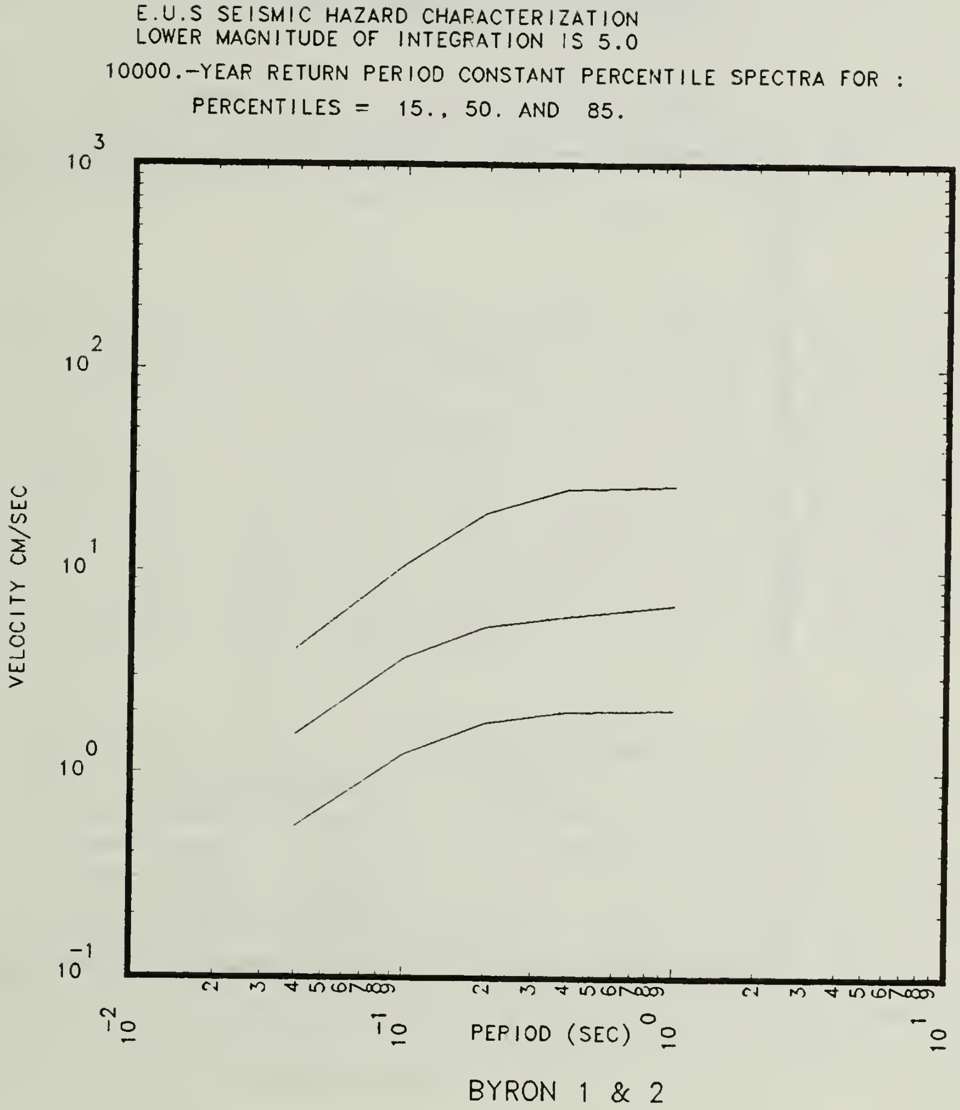


Figure 2.4.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Byron site.

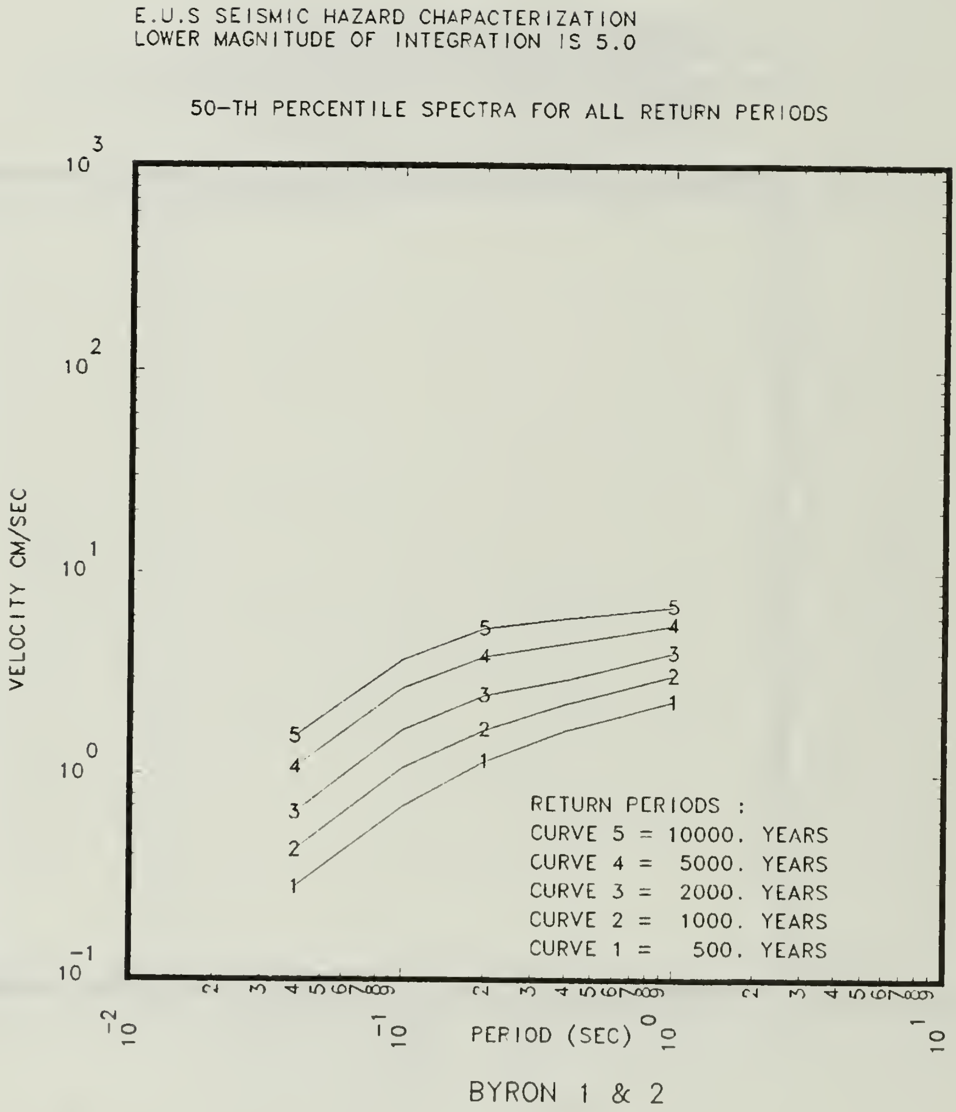


Figure 2.4.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Byron site.

2.5 CLINTON

The Clinton site's soil category is till-like 2 and it is represented by the symbol "5" in Fig. 1.1. Table 2.5.1 and Figs. 2.5.1 through 2.5.10 give the basic results for the Clinton site.

We see from Fig. 2.5.1 that the spread between the BEHC and the AMHC is similar to that for a rock site, e.g., see Fig. 2.3.1. See Vol. VI for a discussion of the effects of site soil types. One reason for this somewhat atypical result is because as can be seen from Fig. 1.1, the Clinton site is relatively near the New Madrid zone hence large earthquakes are important.

We see from Fig. 2.5.2 that there is a wide spread between the S-Experts BEHCs. S-Expert 11's BEHC is higher than the other BEHCs because the site is in S-Expert 11's zone 10, which as can be seen from the maps in Appendix B, is a zone of higher seismicity than the other zones that various S-Experts have used. S-Expert 12's BEHC is the lowest for the reasons discussed in Section 2.1.1

The spread between the G-Experts' BEHCs per S-Expert shows a wider variation between S-Experts at the Clinton site than typical. Typically for a soil site we would expect the spread between the G-Experts' BEHCs for a given S-Expert to be similar to that shown in Fig. 2.1.11. We see from Table 2.5.1 that only for S-Experts 3, 10, 11 and 13 does the main contribution to the BEHC for PGA come from the host zone. For S-Experts 3, 10, 11 and 13 the spread between the G-Experts' BEHCs per S-Expert are similar to that shown in Fig. 2.1.11. However, there is an important difference for S-Experts 3, 10 and 13 as compared to S-Expert 11. Specifically, for S-Experts 3, 10 and 13's input G-Expert 5's BEHC is slightly higher than for other G-Experts' BEHCs, see Fig. 2.5.11, whereas for S-Expert 11's input G-Expert 5's BEHC is slightly lower than G-Expert 2's BEHC as is the case in Fig. 2.1.12.

For the other S-Experts, S-Experts 1, 2, 4, 5, 6, 7 and 12, the spread between the G-Experts' BEHCs per S-Expert is larger than shown in Figs. 2.1.11 and 2.5.11. The spread between the G-Experts' BEHCs for S-Experts 1, 2, and 6 is similar to the spread shown in Fig. 2.5.12 and the spread between the G-Experts' BEHCs for S-Experts 4, 5, 7 and 12 is similar to that shown in Fig. 2.5.13. It is evident, by comparing Figs. 2.5.11, 2.5.12 and 2.5.13, that the zonation, seismicity parameters and GM models interact in interesting ways to produce significantly different estimates of the seismic hazard for a particular site. These wide variations in the estimate of the seismic hazard at the Clinton site explain why there is a wide spread between the AMHC and the BEHC at the Clinton site shown in Fig. 2.5.1 and to some extent the wide spread between the S-Experts' BEHCs.

Figure 2.5.4 indicates that the larger earthquakes are significant at the (shallow soil) Clinton site. It is interesting to note that earthquakes in magnitude range of 5.75 to 6.5 contribute a bit more to that BEHC for PGA at the Clinton site than do earthquakes greater than magnitude 6.5. This is in particular due to the site correction being made. If Clinton was a rock site,

we would have found that earthquakes with magnitudes greater than 6.5 would contribute most to the BEHC for PGA at the Clinton site similar to what we found for the Byron and Braidwood sites. We see also from Fig. 2.5.4 that if earthquakes in the range of 3.75 to 5 were included, there would be little increase in the BEHC for PGA except at very low g-values.

TABLE 2.5.1

MOST IMPORTANT ZONES PER S-EXPERT FOR CLINTON

SITE SOIL CATEGORY TILL-2

S-XPT NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 15	ZONE ID:	ZONE 11	ZONE 9	ZONE 10	ZONE 19	ZONE 11	ZONE 9	ZONE 10	ZONE 15
		% CONT.:	67.	18.	11.	2.	77.	18.	4.	1.
2	ZONE 21	ZONE ID:	ZONE 18	ZONE 20	ZONE 21	COMP. ZON	ZONE 18	ZONE 21	ZONE 20	COMP. ZON
		% CONT.:	53.	25.	19.	2.	73.	22.	3.	1.
3	ZONE 16	ZONE ID:	ZONE 16	ZONE 12	ZONE 13	ZONE 11	ZONE 16	ZONE 12	ZONE 13	COMP. ZON
		% CONT.:	43.	40.	12.	3.	77.	17.	5.	0.
4	ZONE 13	ZONE ID:	ZONE 4	ZONE 5	ZONE 3	ZONE 6	ZONE 4	ZONE 5	ZONE 13	ZONE 3
		% CONT.:	56.	37.	3.	2.	80.	18.	1.	0.
5	COMP. ZO	ZONE ID:	ZONE 15	ZONE 14	COMP. ZON	ZONE 12	ZONE 15	COMP. ZON	ZONE 14	ZONE 4
		% CONT.:	74.	21.	2.	2.	97.	2.	1.	0.
6	ZONE 22	ZONE ID:	ZONE 17	ZONE 22	ZONE 18	ZONE 9	ZONE 17	ZONE 22	ZONE 18	COMP. ZON
		% CONT.:	88.	8.	3.	1.	87.	11.	1.	1.
7	ZONE 2 =	ZONE ID:	ZONE 6	ZONE 5	ZONE 2 =	ZONE 34	ZONE 6	ZONE 2 =	ZONE 5	ZONE 4
		% CONT.:	82.	14.	3.	0.	94.	4.	2.	0.
10	ZONE 19	ZONE ID:	ZONE 19 =	ZONE 13	ZONE 12A	ZONE 26A	ZONE 19 =	ZONE 12A	ZONE 13	ZONE 26A
		% CONT.:	63.	18.	17.	2.	96.	3.	1.	0.
11	ZONE 10	ZONE ID:	ZONE 10	ZONE 11	CZ = ZONE	ZONE 15	ZONE 10	ZONE 11	CZ = ZONE	ZONE 5
		% CONT.:	97.	2.	1.	0.	100.	0.	0.	0.
12	ZONE 4 =	ZONE ID:	ZONE 13	ZONE 15	ZONE 14	ZONE 19	ZONE 15	ZONE 13	ZONE 14	ZONE 5
		% CONT.:	55.	30.	15.	0.	85.	9.	6.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 5	ZONE 6	ZONE 4	CZ 15	ZONE 5	ZONE 6	ZONE 1
		% CONT.:	45.	34.	20.	1.	81.	18.	1.	0.

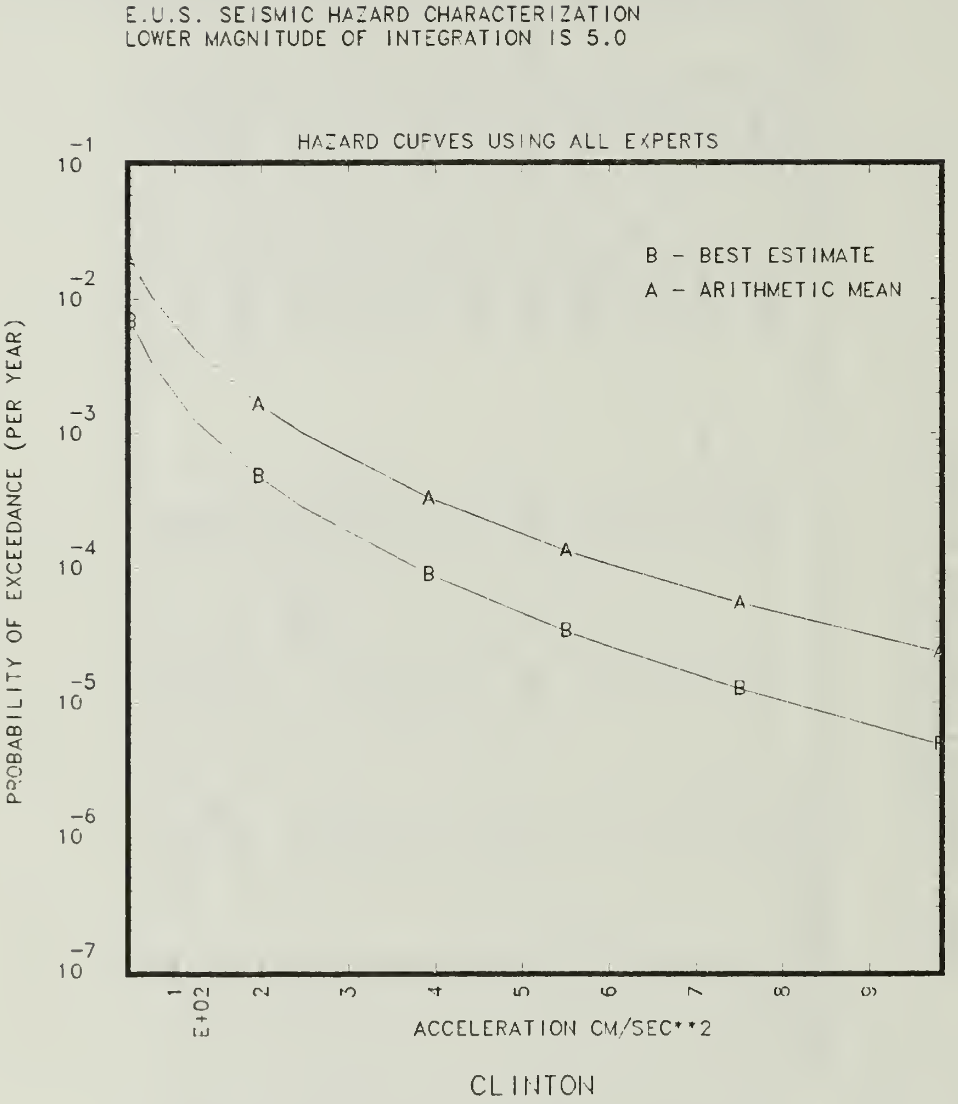


Figure 2.5.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Clinton site.

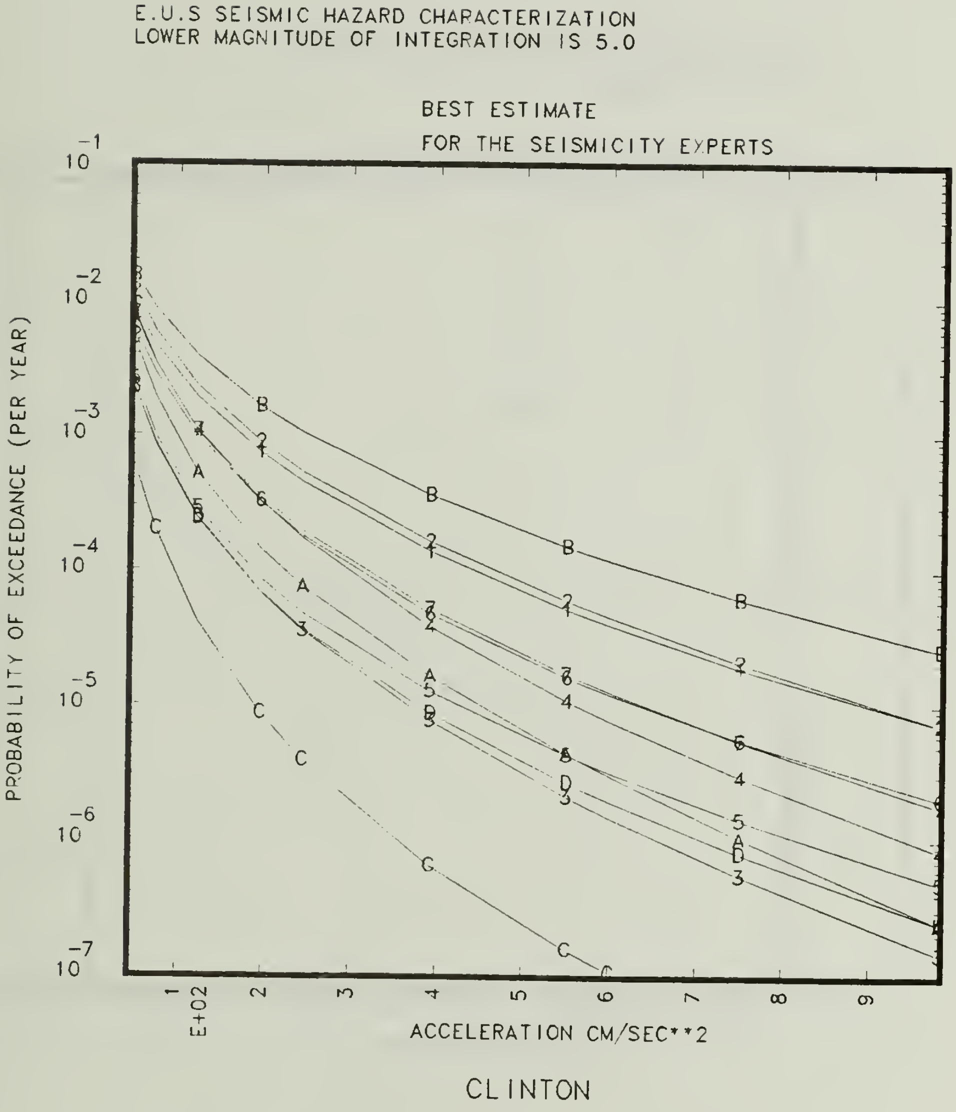


Figure 2.5.2 BEHCs per S-Expert combined over all G-Experts for the Clinton site. Plot symbols given in Table 2.0.

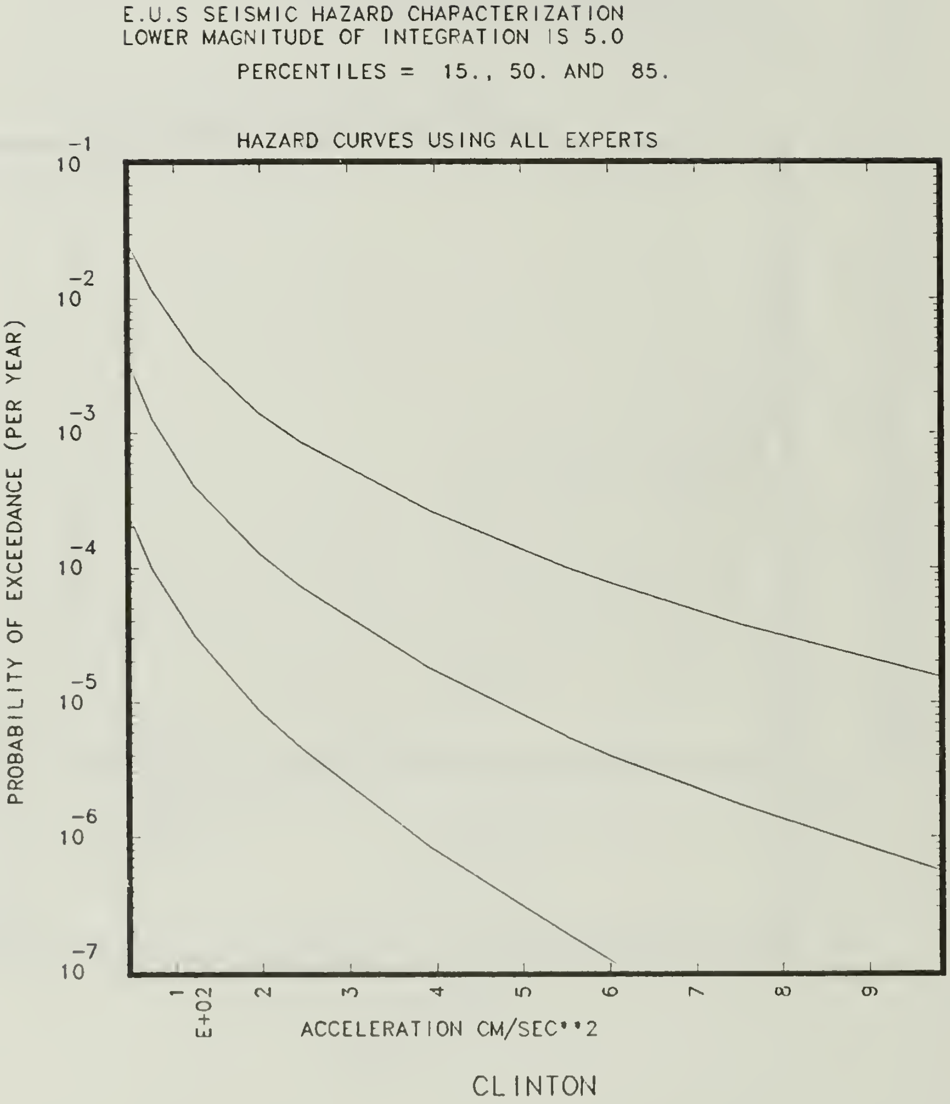
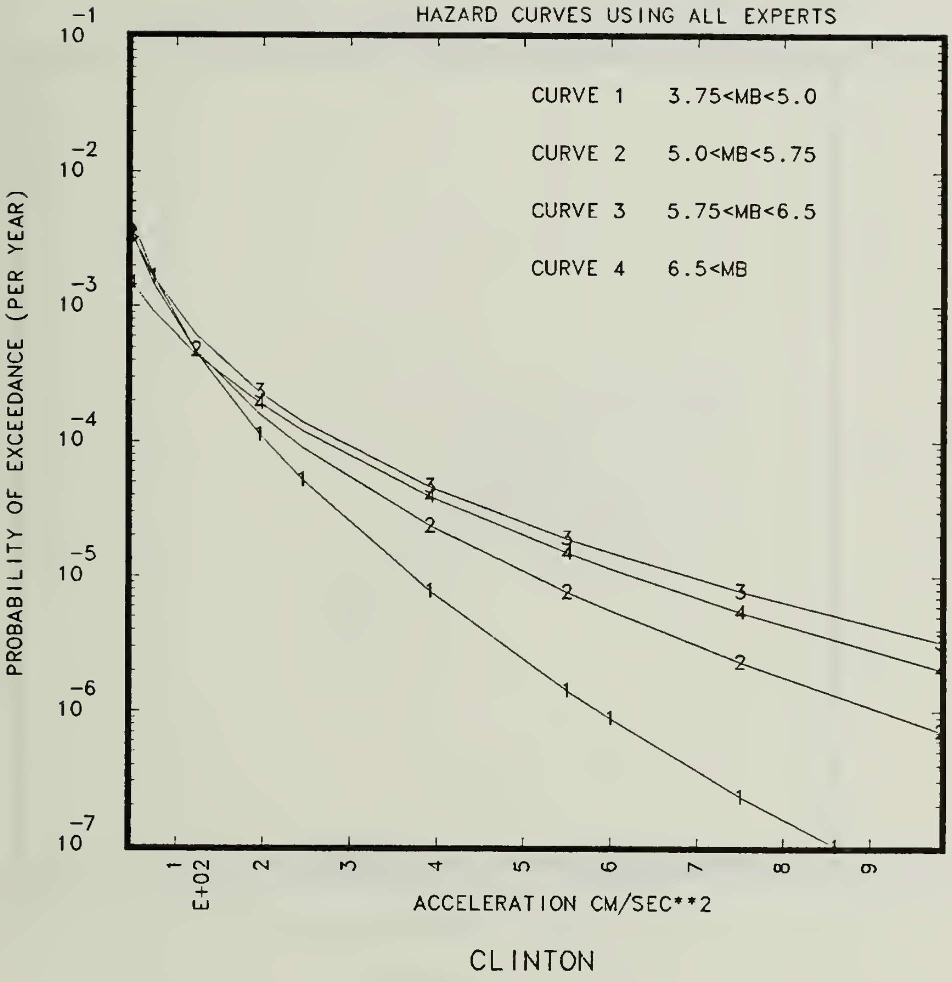


Figure 2.5.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Clinton site.



igure 2.5.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Clinton site.

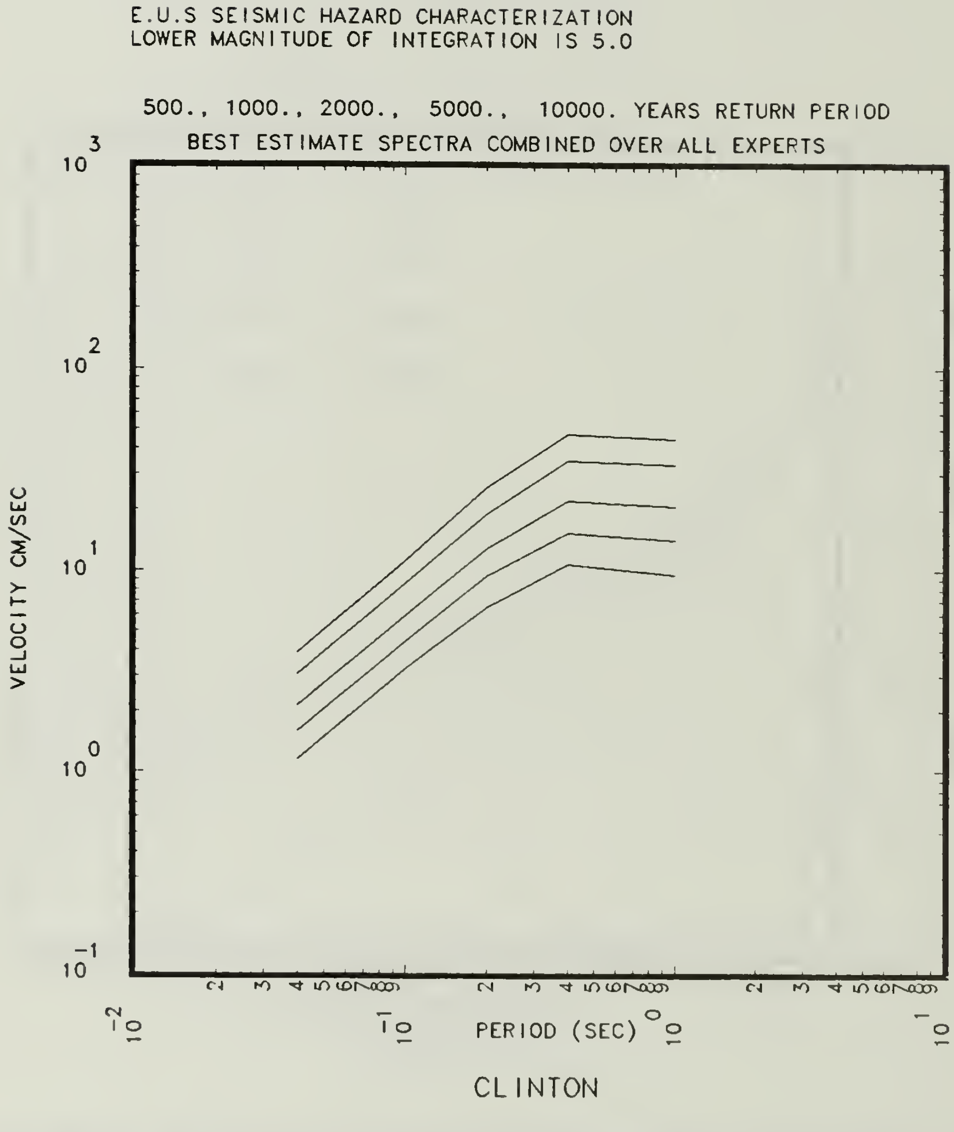


Figure 2.5.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Clinton site.

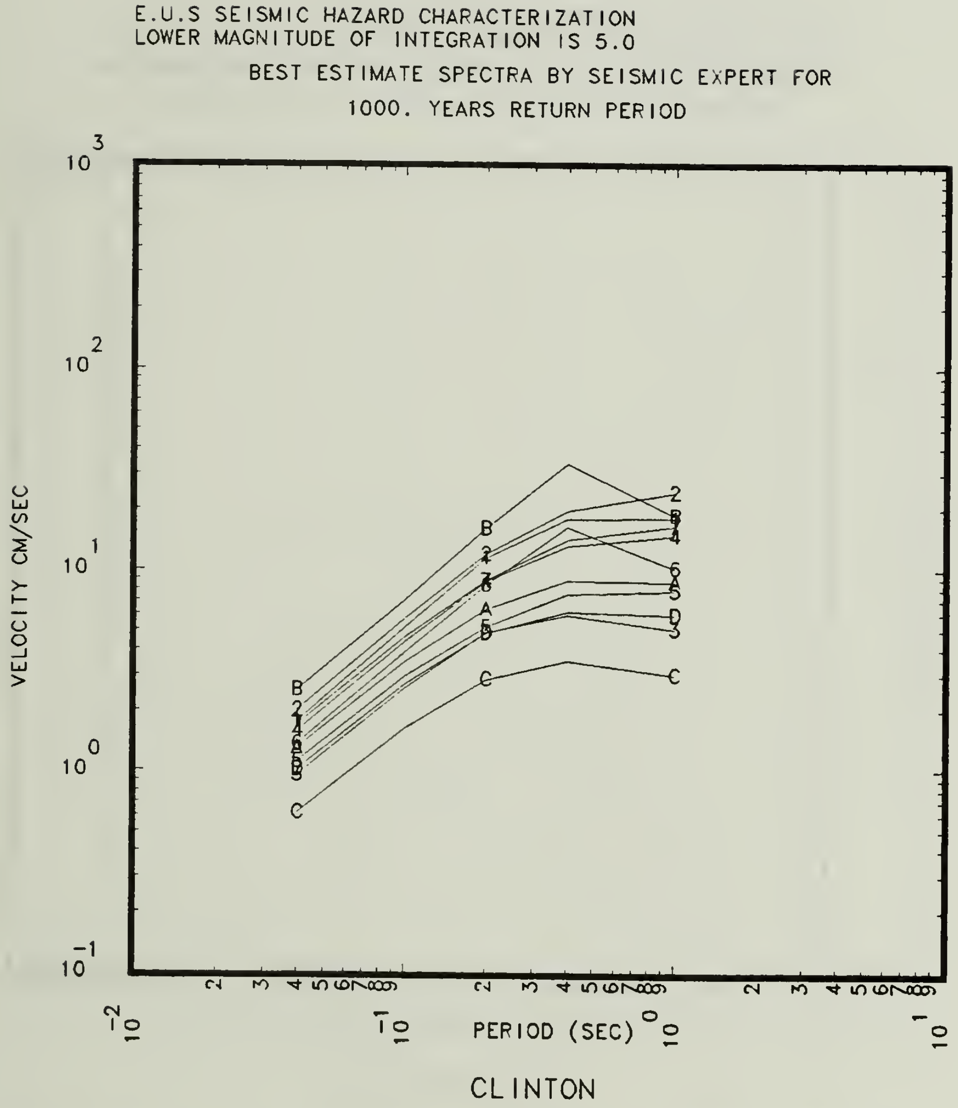


Figure 2.5.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Clinton site. Plot symbols are given in Table 2.0.

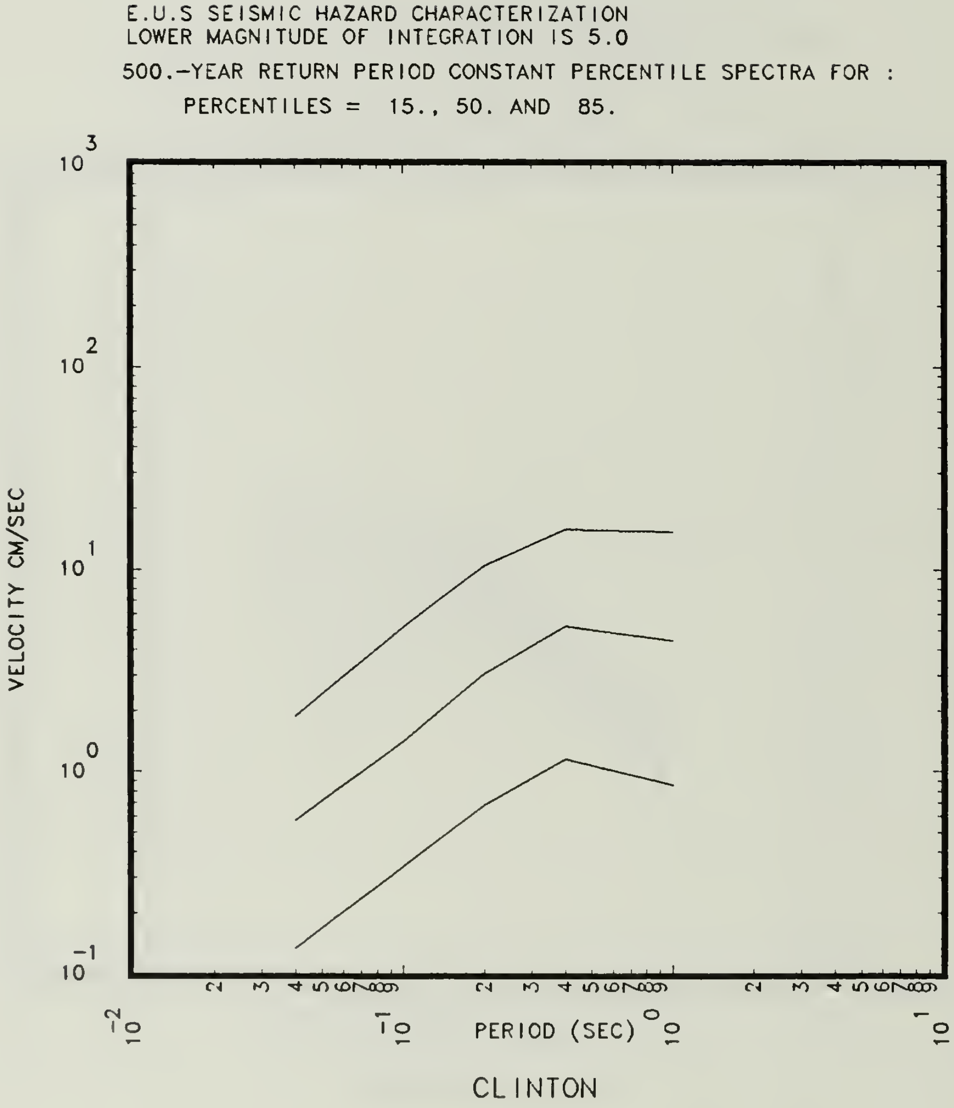


Figure 2.5.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Clinton site.

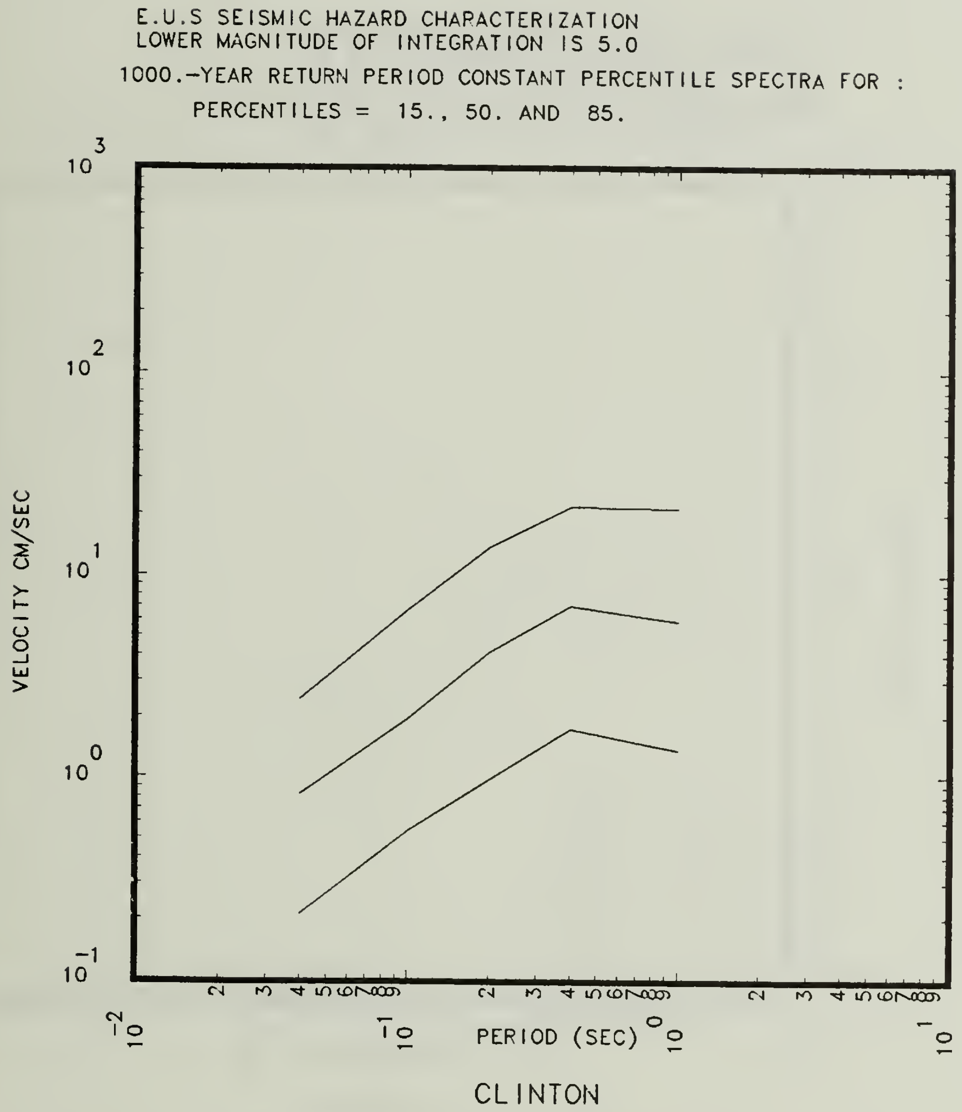


Figure 2.5.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Clinton site.

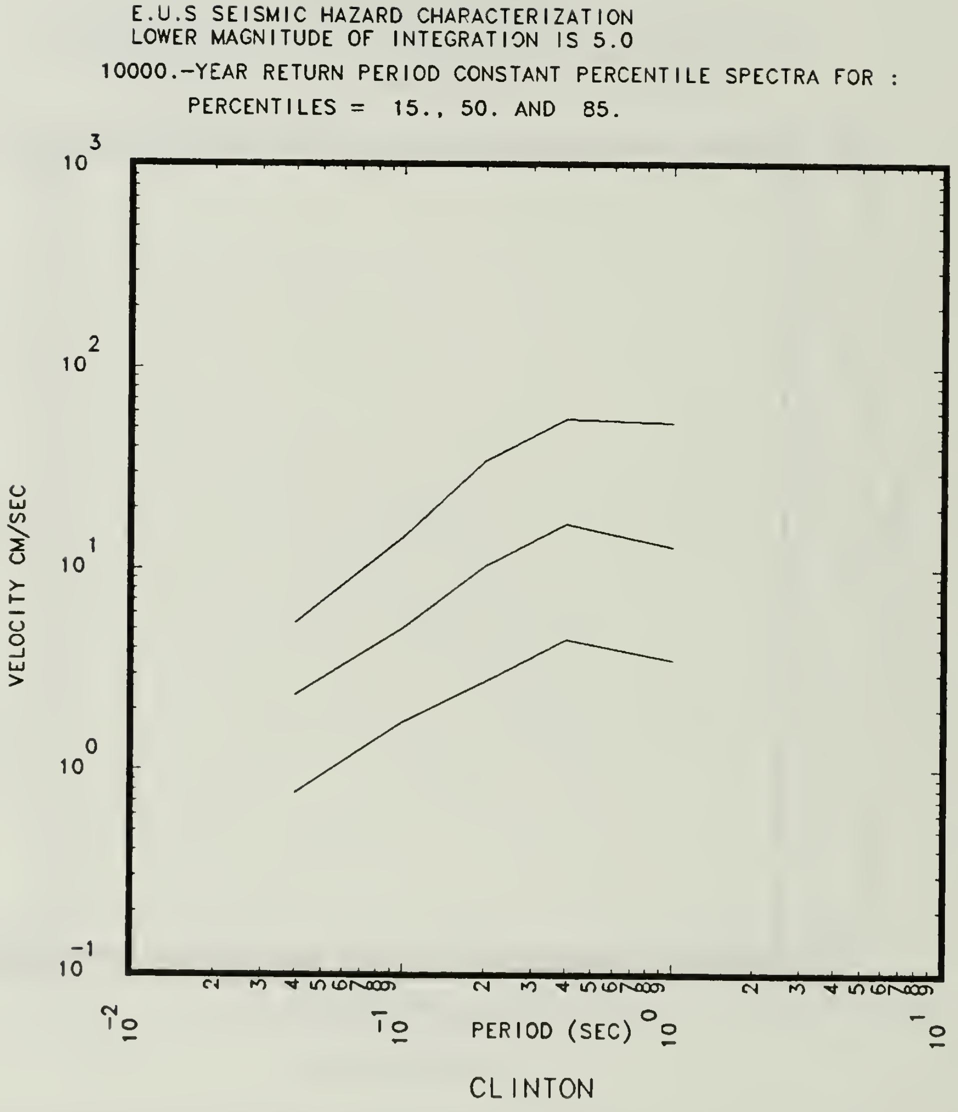


Figure 2.5.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Clinton site.

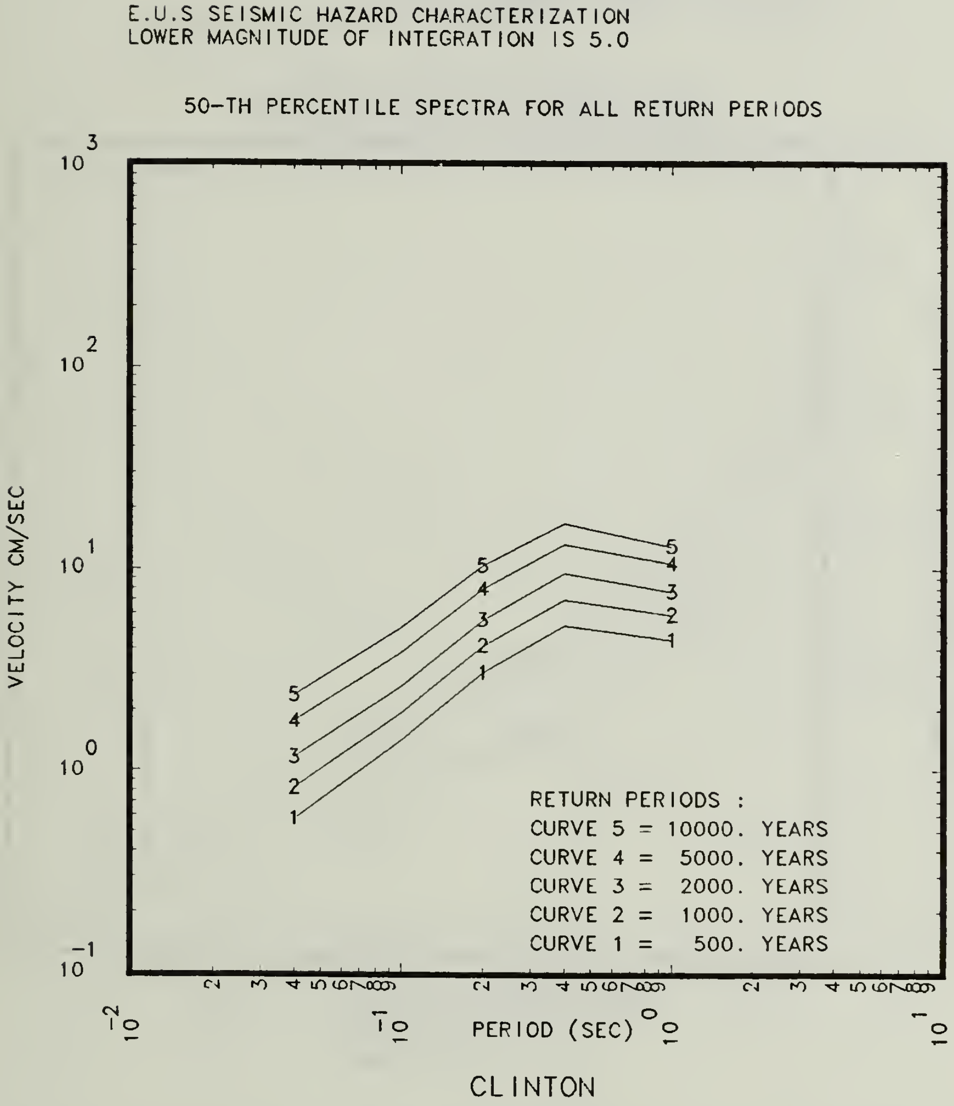


Figure 2.5.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Clinton site.

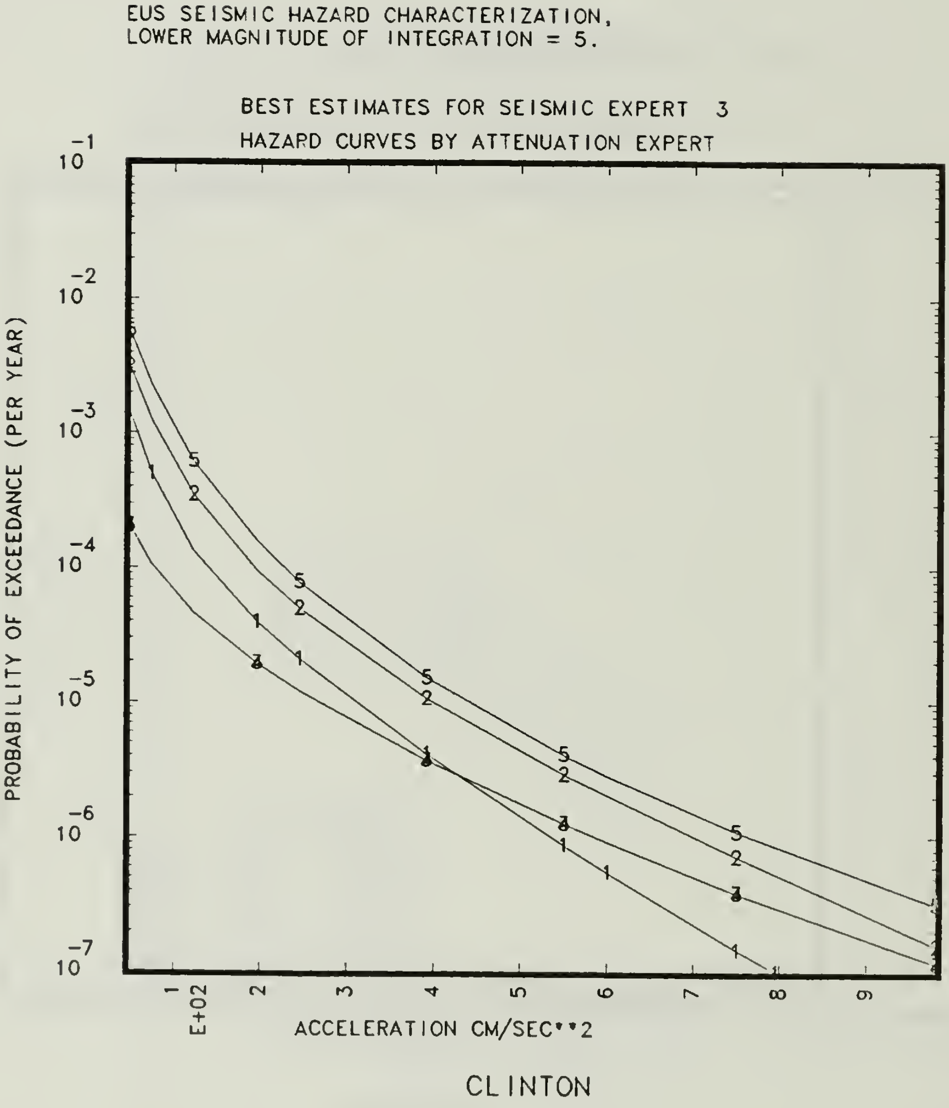


Figure 2.5.11 The BEHCs per G-Expert for S-Expert 3's input for the Clinton site. The spread between the G-Experts' BEHCs is similar for S-Experts' 3, 10 and 13 input for the Clinton site.

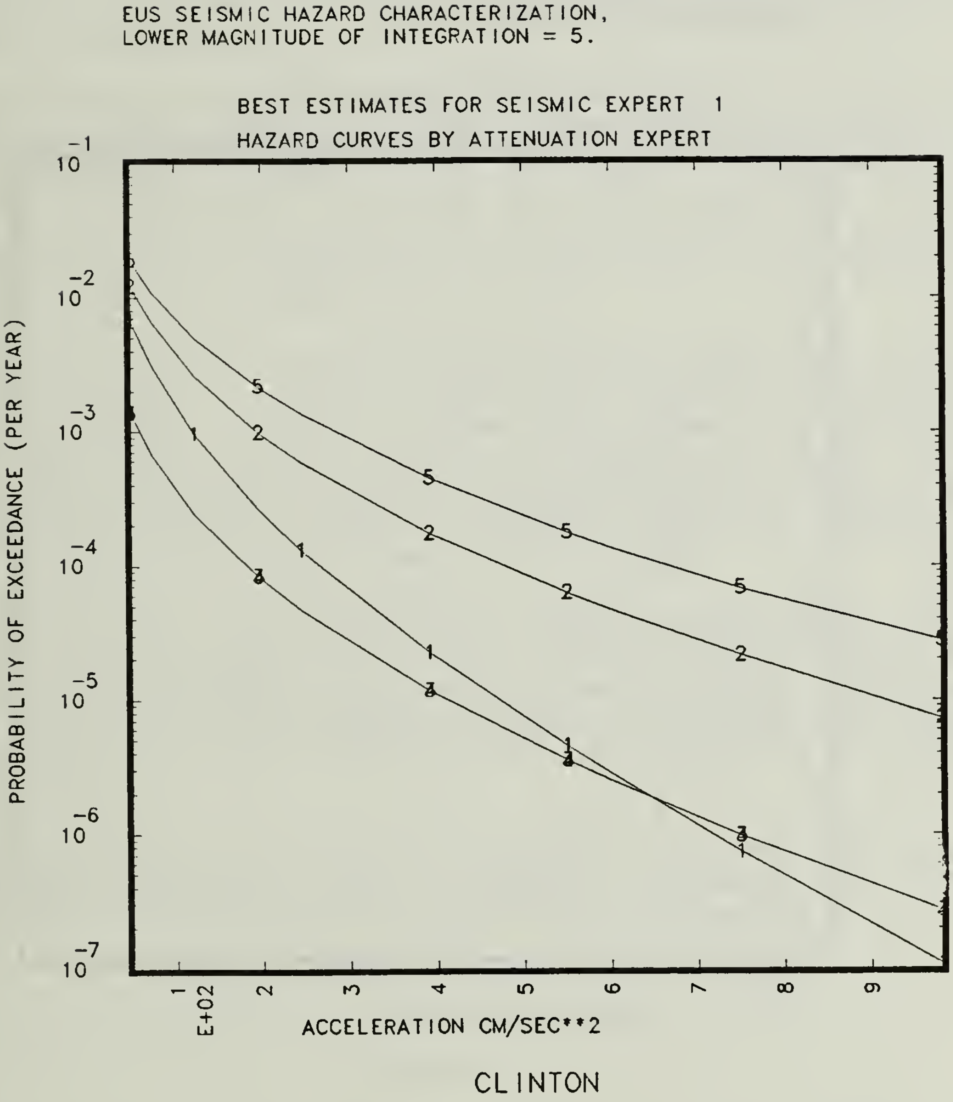


Figure 2.5.12 The BEHCs per G-Expert for S-Expert 1's input for the Clinton site. The spread between the G-Experts' BEHCs is similar for S-Experts 2 and 6.

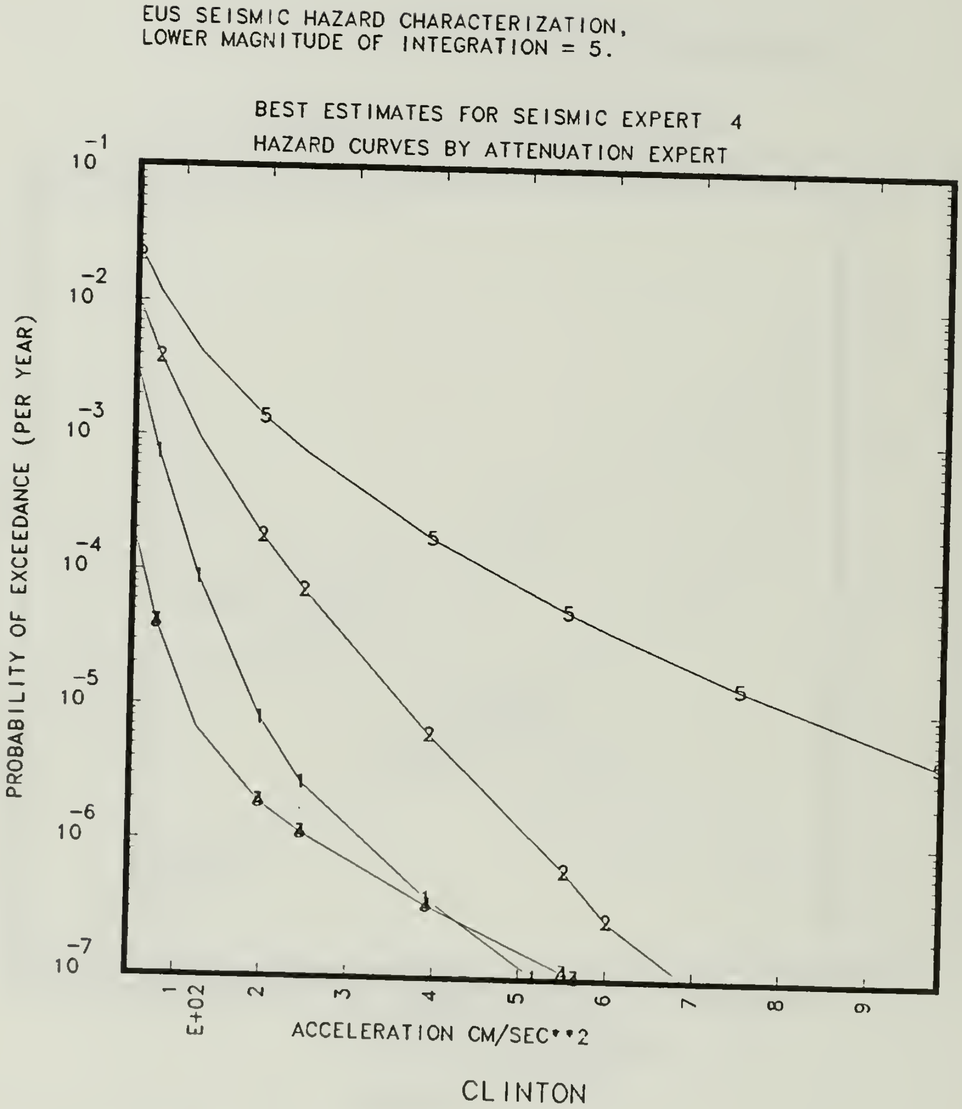


Figure 2.5.13 The BEHCs per G-Expert for S-Expert 4's input for the Clinton site. The spread between the G-Experts BEHCs is similar for S-Experts 4, 5, 7 and 12.

2.6 COOK

The Cook site's soil category is sand-like 2 and it is represented by the symbol "6" in Fig. 1.1. Table 2.6.1 and Figs. 2.6.1 through 2.6.10 give the basic results for the Cook site.

We see by comparing Fig. 2.6.1 to 2.6.3 that the median CPHC is close to the BEHC. The AMHC is slightly higher than the 85th percentile CPHC. It can be seen from Fig. 2.6.2 except for S-Expert 12's BEHC there is a relatively small spread between the other S-Experts' BEHCs. S-Expert 12's BEHC is low because, as discussed in Section 2.1.1 he set the upper magnitude cut off for his CZ zone 4, which is the zone which is the host zone for the Cook site for S-Expert 12's zonation to 5.

We see from Table 2.6.1 that for S-Experts 3, 6, 11 and 13 the host zone is also the zone which contributes most to the BEHC for PGA for the Cook site. We see from the maps in Appendix A that for S-Expert 10 that the site is in zone 27 but it is very near to zone 26A which contributes most to the BEHC for PGA based on S-Expert 10's input for the Cook site. As would be expected for these S-Experts the spread between the G-Experts' BEHCs is relatively small and similar to the spread shown in Fig. 2.1.11.

For S-Experts 1, 2, and 7's zonation and seismicity models the spread between the G-Experts' BEHCs per S-Expert is much larger and similar to the spread shown in Fig. 2.6.11. It should be noted that S-Expert 2's zone 23 is not listed in Table 2.6.1 because S-Expert 2 only assigned a degree of belief of 0.3 to zone 23, thus zone 23 is not part of the BE map for S-Expert 2. The spread between the G-Experts' BEHCs is slightly larger for S-Experts 4, 5 and 12 and is similar to the spread shown in Fig. 2.5.13.

We see from Fig. 2.6.4 the all magnitude ranges contribute more or less equally to the BEHC for PGA. If we examined the individual sets of curves for each S-Expert of course the picture would be much different. For example, for S-Experts 3, 6, 10, 11 and 13 smaller magnitude earthquakes would be most significant and for the other S-Experts the larger magnitude earthquakes would be most significant.

We also see from Fig. 2.6.4 that if earthquakes in the magnitude range 3.75 to 5 were included that the BEHC for PGA would be increased by about a factor of 2 in 0.05g to 0.4g range in annual probability of exceedance.

TABLE 2.6.1

MOST IMPORTANT ZONES PER S-EXPERT
FOR COOK 1 & 2

SITE SOIL CATEGORY SAND-2

S-XPT NUM.	MOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 15	ZONE ID:	ZONE 9	ZONE 19	ZONE 11	ZONE 15	ZONE 9	ZONE 15	ZONE 19	ZONE 11
		% CONT.:	35.	29.	16.	10.	43.	27.	24.	5.
2	COMP. ZO	ZONE ID:	ZONE 18	COMP. ZON	ZONE 20	ZONE 21	ZONE 18	COMP. ZON	ZONE 20	ZONE 21
		% CONT.:	69.	21.	8.	1.	55.	45.	0.	0.
3	ZONE 15	ZONE ID:	ZONE 15	ZONE 16	ZONE 11	ZONE 13	ZONE 15	COMP. ZON	ZONE 16	ZONE 13
		% CONT.:	76.	8.	8.	4.	97.	2.	0.	0.
4	ZONE 13	ZONE ID:	ZONE 4	ZONE 6	ZONE 5	ZONE 27	ZONE 4	ZONE 13	ZONE 6	ZONE 27
		% CONT.:	58.	22.	7.	5.	75.	19.	4.	1.
5	COMP. ZO	ZONE ID:	ZONE 15	ZONE 12	COMP. ZON	ZONE 14	ZONE 15	COMP. ZON	ZONE 12	ZONE 1
		% CONT.:	44.	43.	6.	3.	74.	22.	4.	0.
6	ZONE 22	ZONE ID:	ZONE 22	ZONE 17	ZONE 9	COMP. ZON	ZONE 22	COMP. ZON	ZONE 17	ZONE 9
		% CONT.:	51.	24.	13.	7.	90.	4.	4.	1.
7	ZONE 2 =	ZONE ID:	ZONE 6	ZONE 2 =	ZONE 34	ZONE 5	ZONE 6	ZONE 2 =	ZONE 34	ZONE 5
		% CONT.:	76.	13.	4.	4.	66.	34.	0.	0.
10	ZONE 27	ZONE ID:	ZONE 26A	ZONE 27	ZONE 19 =	ZONE 12A	ZONE 26A	ZONE 27	ZONE 19 =	ZONE 4B
		% CONT.:	77.	13.	4.	4.	48.	36.	16.	0.
11	CZ = ZON	ZONE ID:	CZ = ZONE	ZONE 10	ZONE 11	ZONE 9	CZ = ZONE	ZONE 10	ZONE 11	ZONE 9
		% CONT.:	79.	16.	3.	1.	99.	1.	0.	0.
12	ZONE 4 =	ZONE ID:	ZONE 15	ZONE 13	ZONE 14	ZONE 31A	ZONE 15	ZONE 5	ZONE 6	ZONE 7
		% CONT.:	55.	20.	13.	4.	100.	0.	0.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 5	ZONE 6	ZONE 7	CZ 15	ZONE 5	ZONE 1	ZONE 3
		% CONT.:	83.	14.	2.	1.	98.	2.	0.	0.

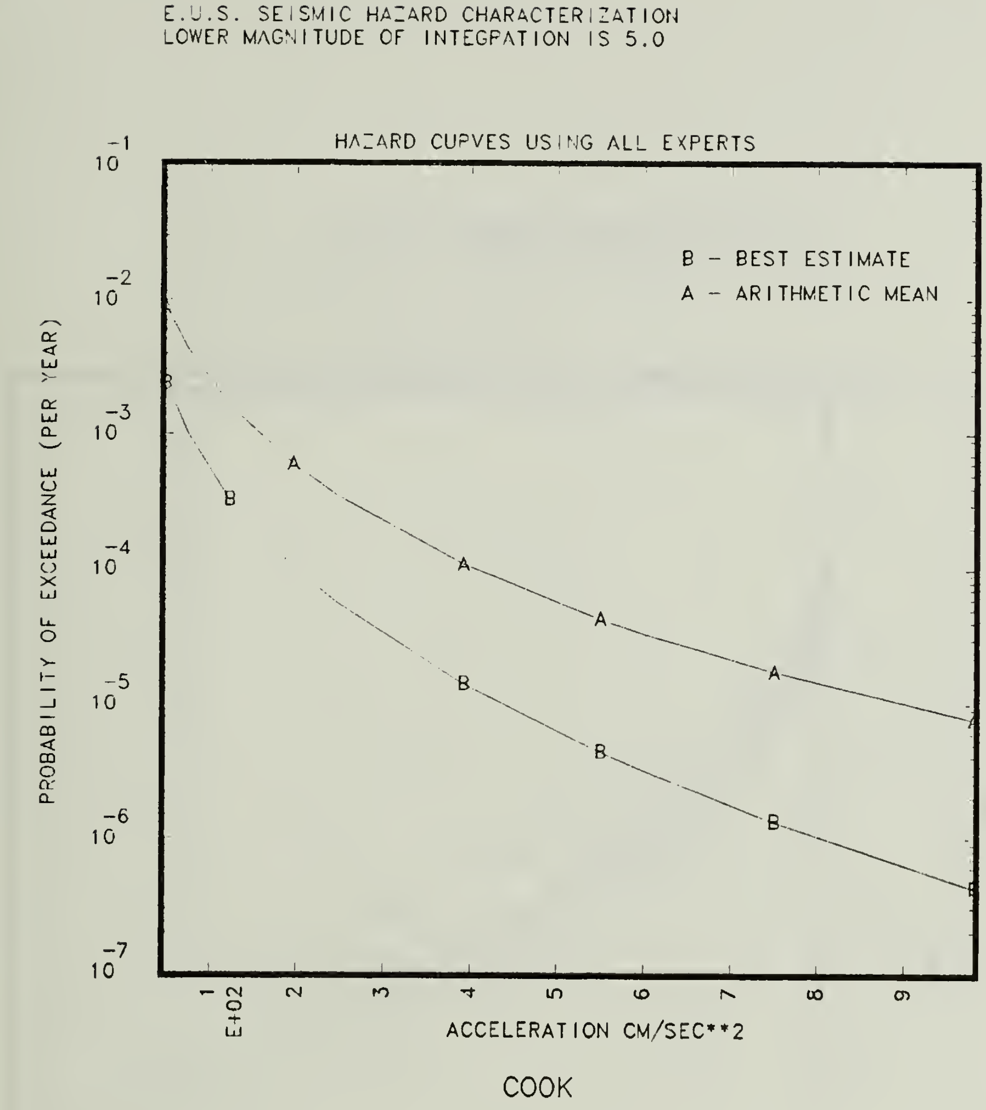


Figure 2.6.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Cook site.

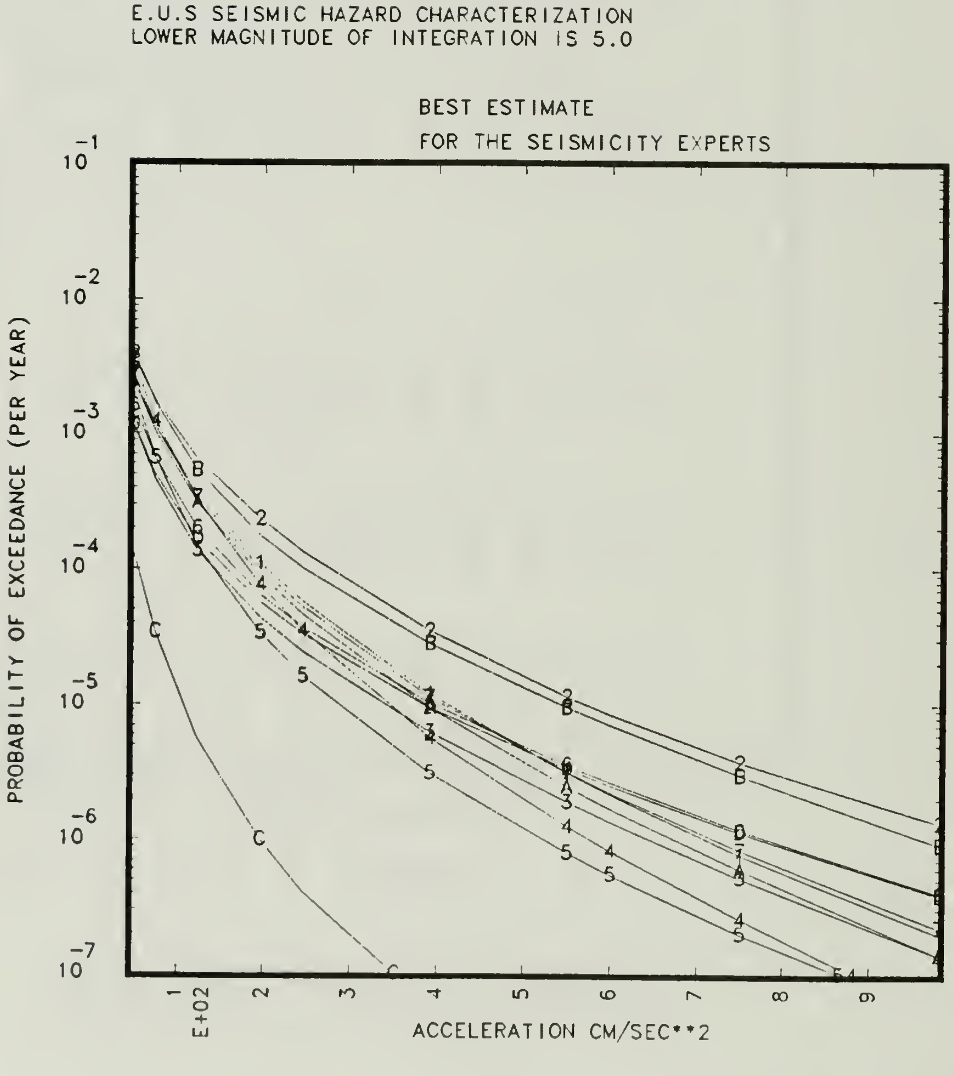


Figure 2.6.2 BEHCs per S-Expert combined over all G-Experts for the Cook site. Plot symbols given in Table 2.0.

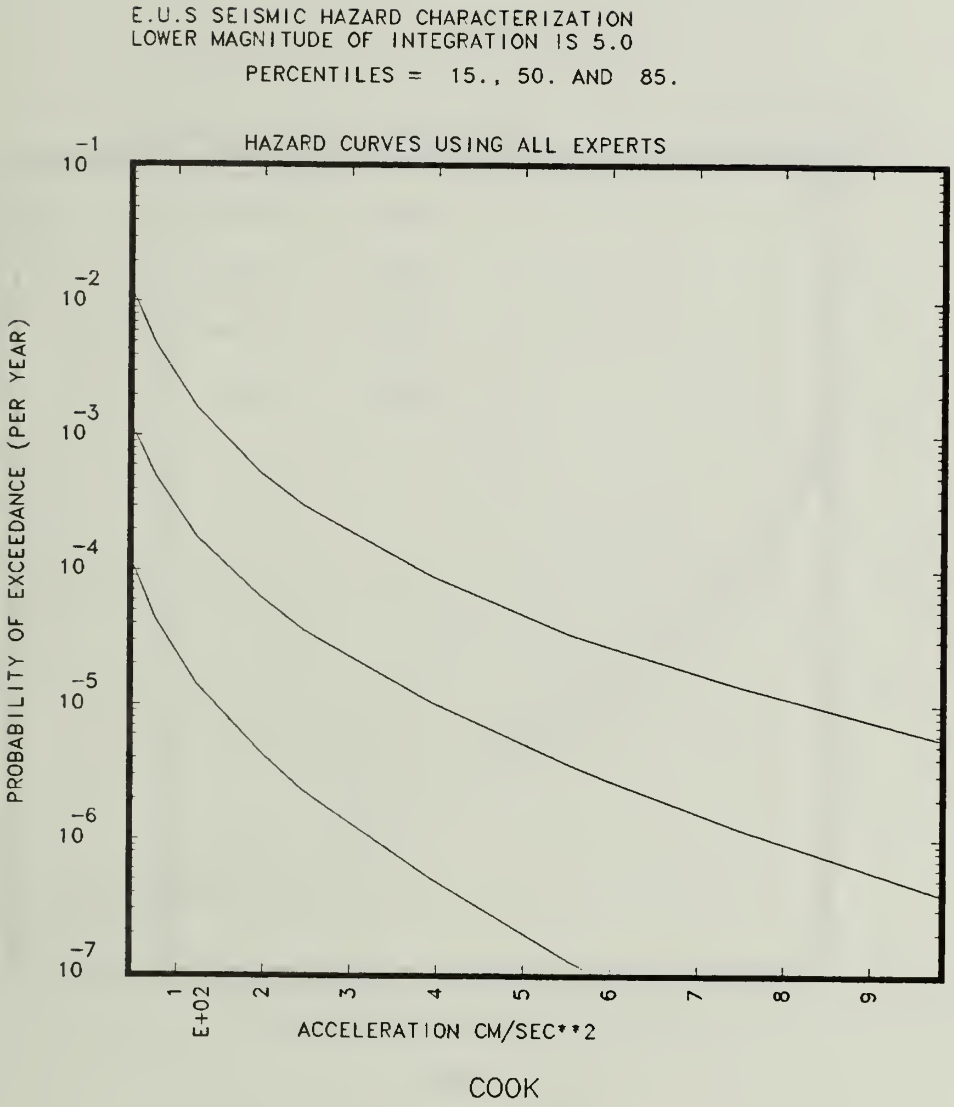


Figure 2.6.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Cook site.

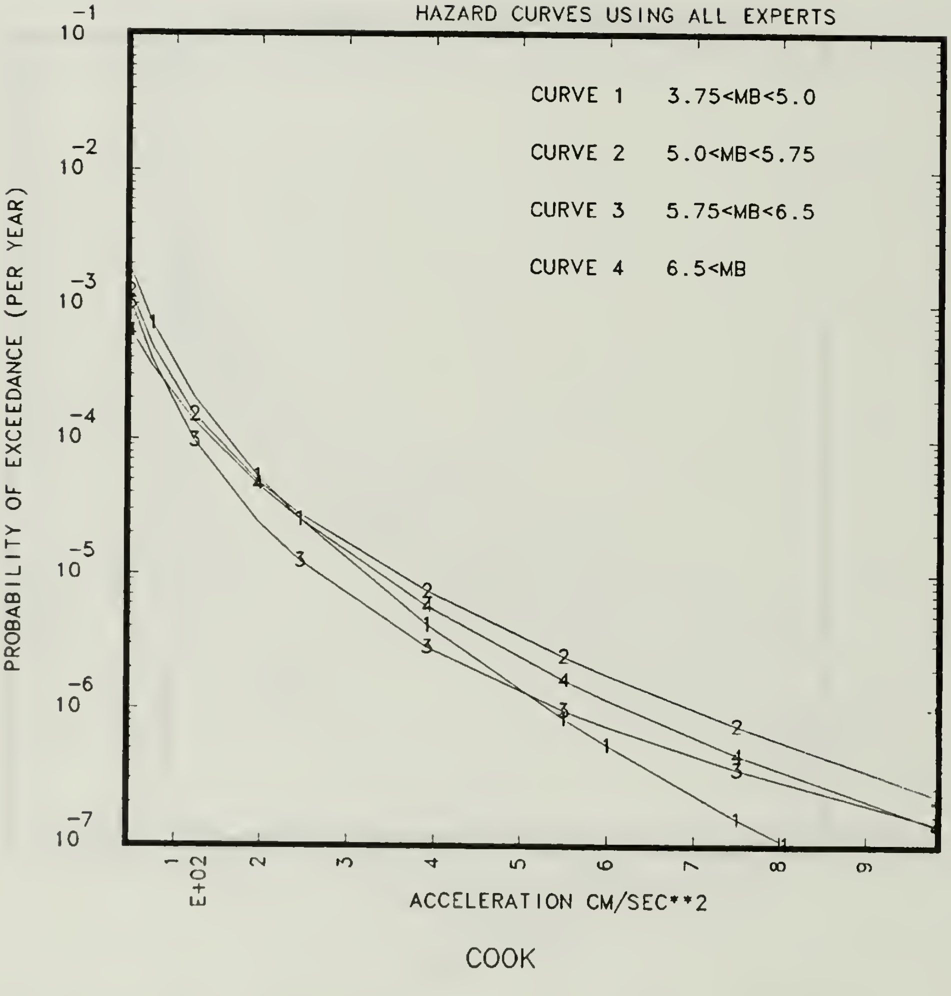


Figure 2.6.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Cook site.

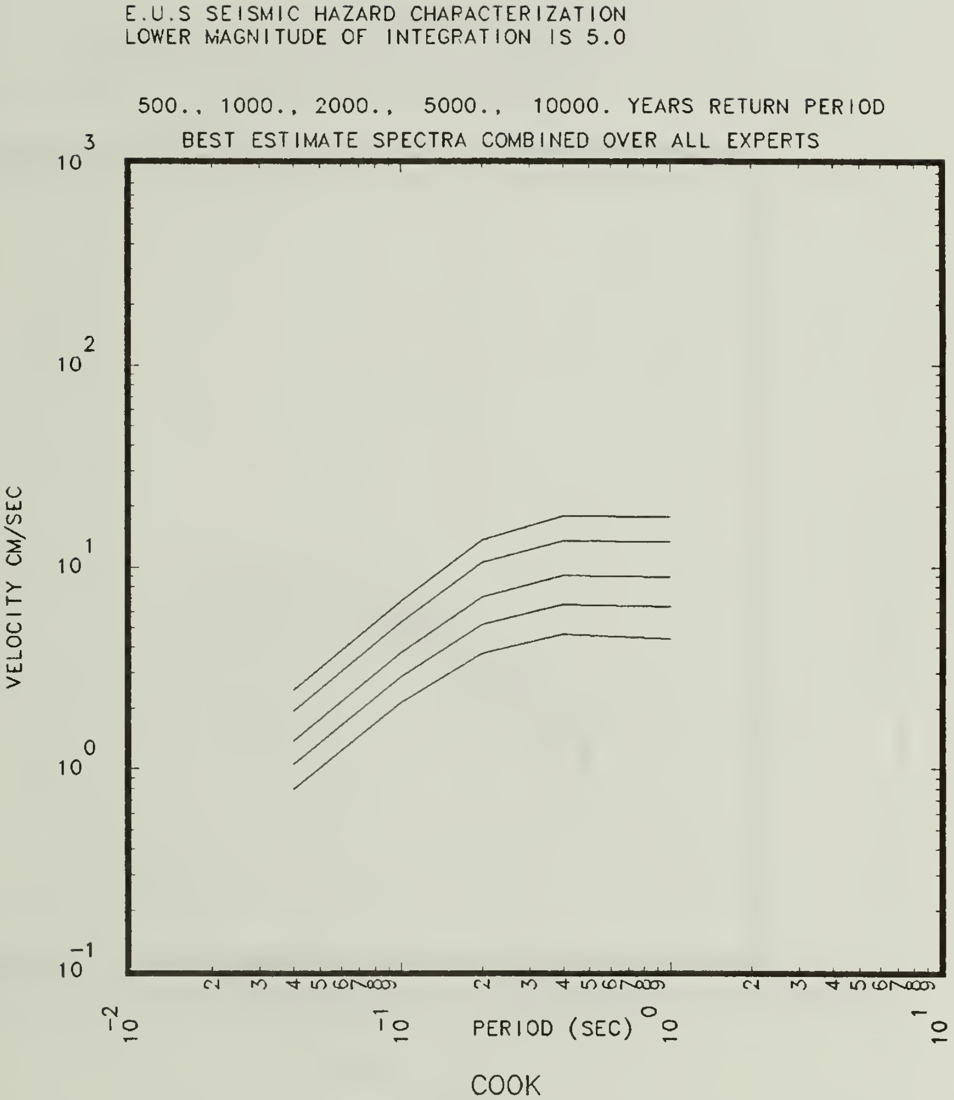


Figure 2.6.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Cook site.

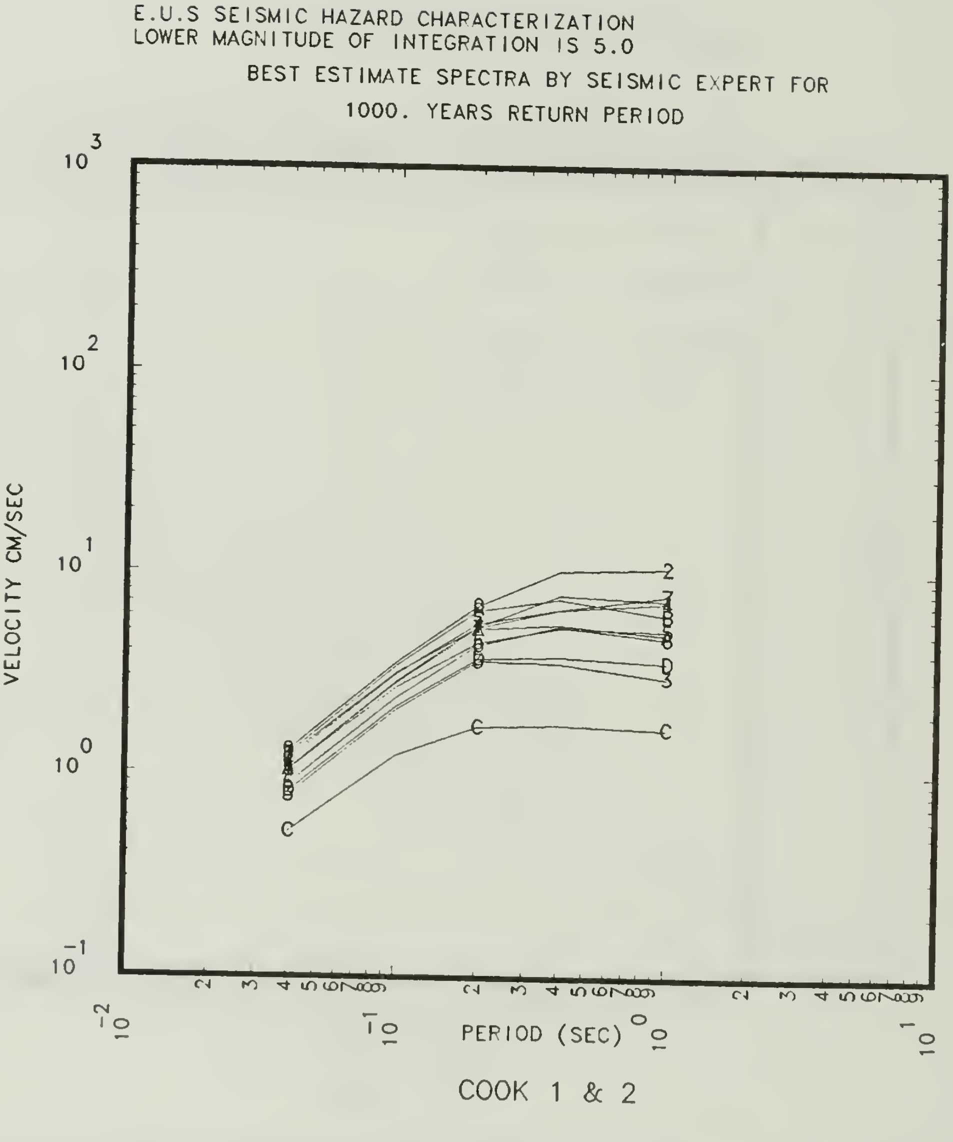


Figure 2.6.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Cook site. Plot symbols are given in Table 2.0.

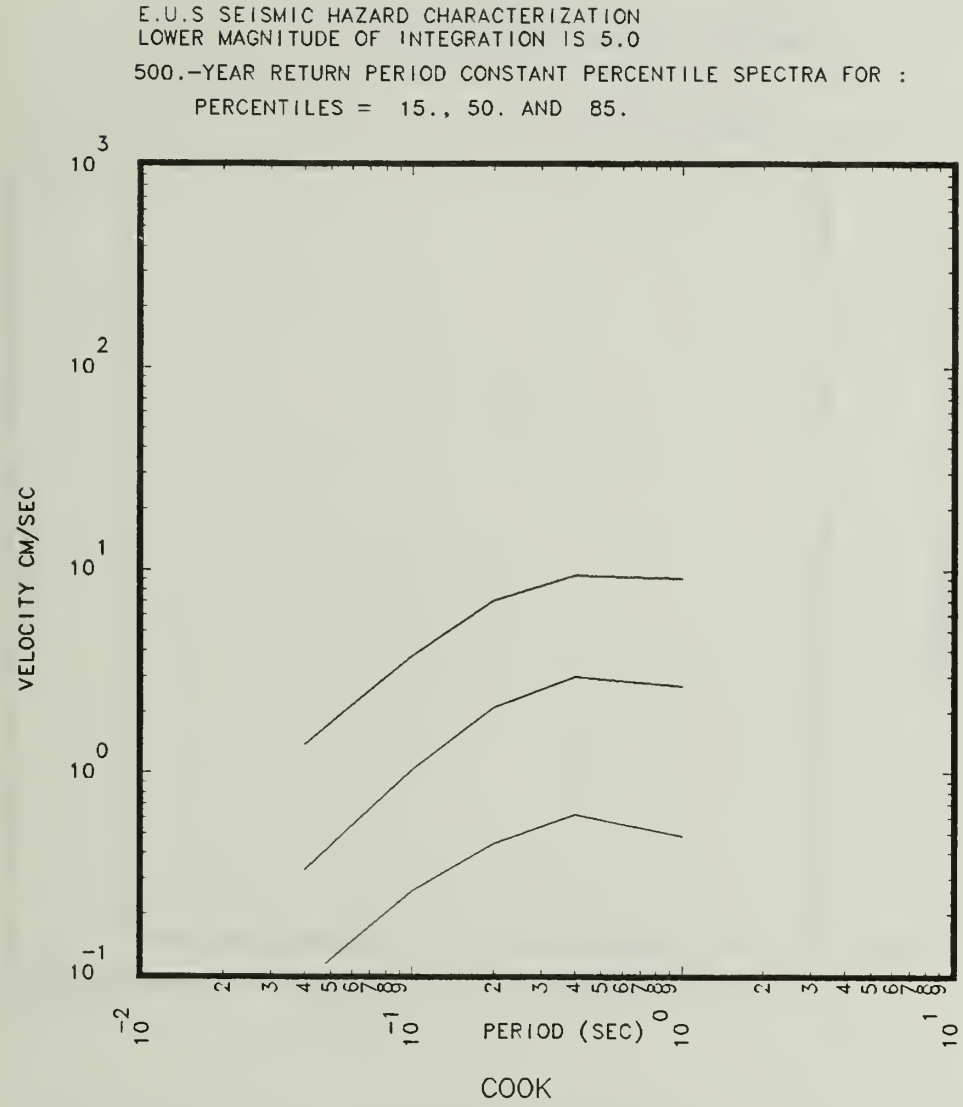


Figure 2.6.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Cook site.

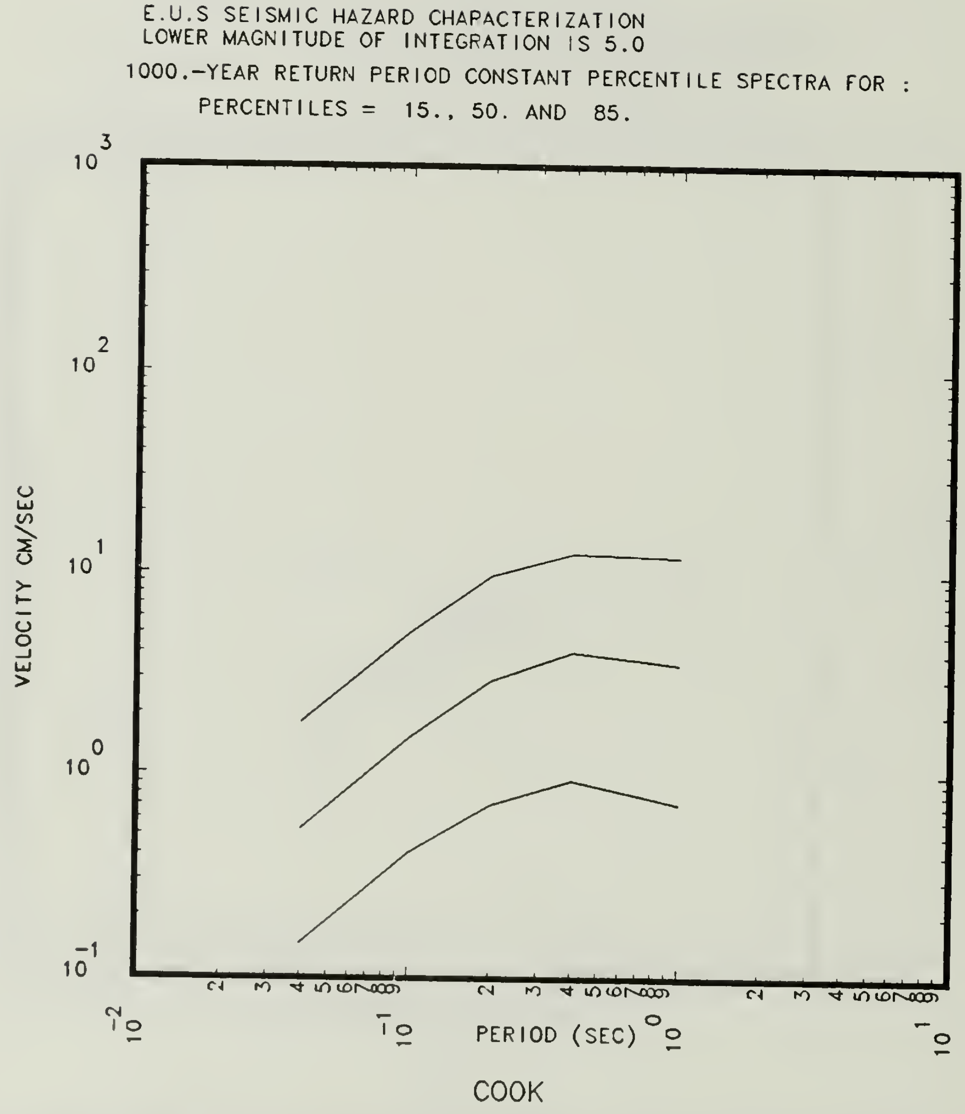


Figure 2.6.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Cook site.

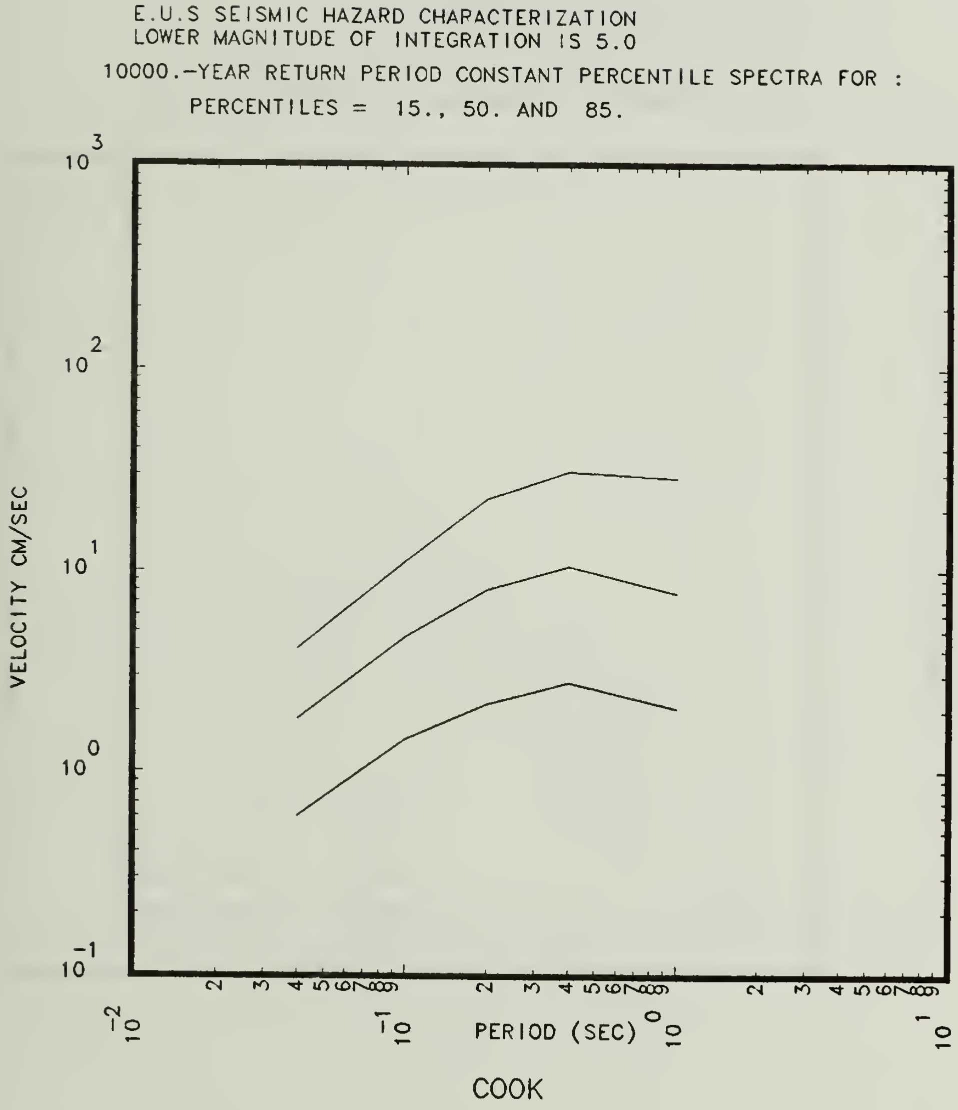


Figure 2.6.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Cook site.

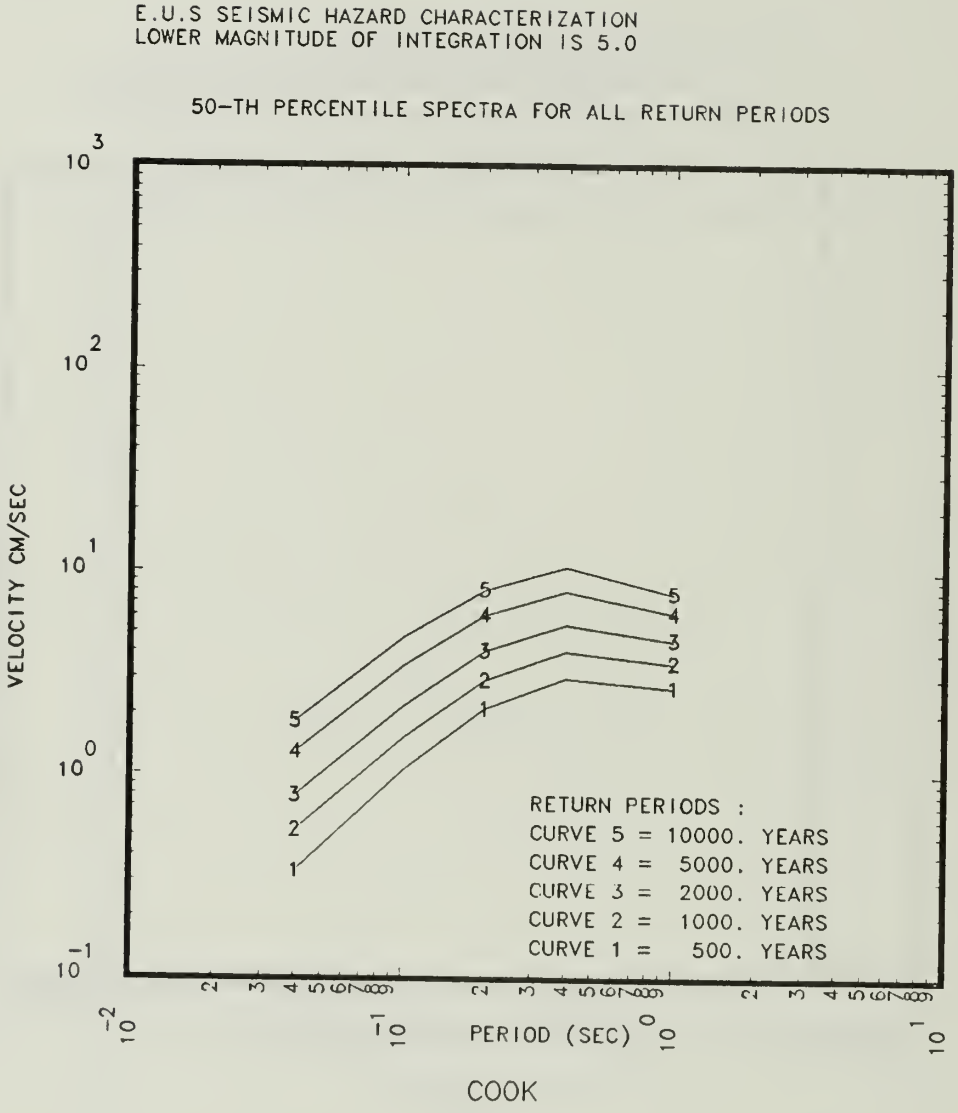


Figure 2.6.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Cook site.

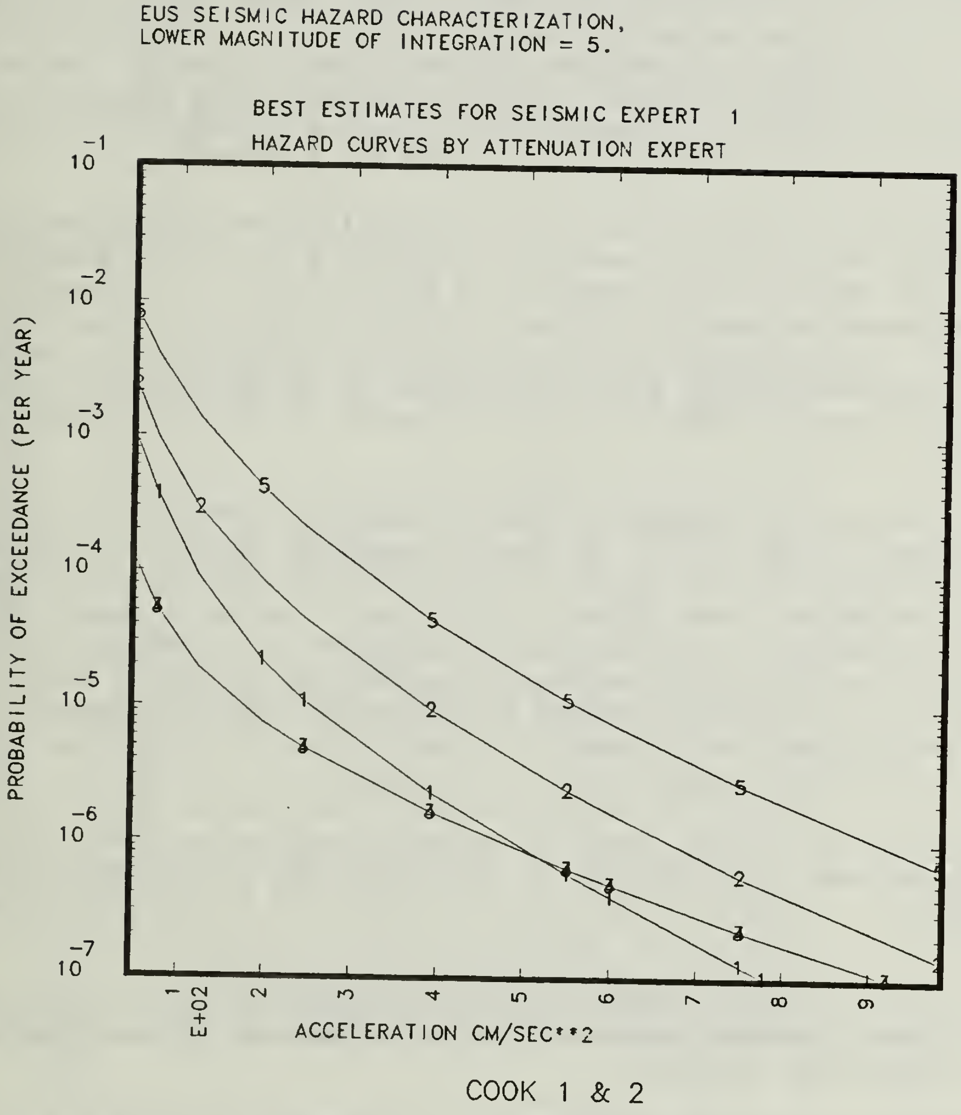


Figure 2.6.11 The BEHCs per G-Expert for S-Expert 1's zonation and seismicity parameters. The spread between G-Experts' BEHCs is also similar for S-Experts 2 and 7 input.

2.7 DAVIS BESSE

The Davis Besse site is a rock site and it is represented by the symbol "7" in Fig. 1.1. Table 2.7.1 and Figs. 2.7.1 through 2.7.10 give the basic result for the Davis Besse site.

The spread between the AMHC and the BEHC is about the same as for the Byron and Braidwood sites indicating that for a number of S-Experts the hazard is dominated by larger earthquakes from more distant zones such as the New Madrid region. This is found to be the case (see Table 2.7.1) for S-Experts 2, 4, 7 and 12. For the other S-Experts most of the hazard is coming from either the host zone or other nearby zones. It should be noted that S-Expert 2's zone 23 is not listed in Table 2.7.1 because it only has a probability of existence of 0.3, therefore does not appear in the BE map for S-Expert 2.

For S-Experts 2, 4, 7 and 12, as would be expected, the spread between G-Experts' BEHCs for these S-Experts is large with G-Expert 5's BEHC being much higher for the three reasons discussed in Section 2.3. For S-Experts 2, 4, 7 and 12 the spread between the G-Experts' BEHCs is similar to that shown in Fig. 2.3.12. For S-Experts 1, 3, 6, 10, 11 and 13 the hazard is coming primarily from nearby zones and, as discussed in Section 2.3, the spread between the G-Experts' BEHCs for these S-Experts is similar to that shown in Fig. 2.3.11.

The spread between the G-Experts' BEHCs is somewhat different for S-Expert 5's input as shown in Fig. 2.7.11. It can be seen from Table 2.7.1 and the maps in Appendix A the hazard at the Davis Besse site for S-Expert 5's zonation and seismicity parameters comes primarily from zone 12 which is nearby the site. This puts the "center" of the source of the hazard at a somewhat greater distance away from the site than for S-Experts 1, 3, 6, 10, 11 and 13 hence the variation in attenuation between the GM models becomes important and thus the BEHCs per G-Expert for S-Expert 5's input spread out more than typical when the source of the hazard is near the site.

We see from Fig. 2.7.2 that there is, as would be expected given the variation in zonation between the S-Experts, a relatively wide spread between the S-Experts' BEHCs. The BEHC for S-Expert 12 is low for the reasons discussed in Section 2.1.1.

The wide variation between BEHCs both between G-Experts per S-Expert and between S-Experts combined over all, G-Experts leads to the wide spread between the AMHC and the BEHC.

We see from Fig. 2.7.4 that earthquakes in the magnitude range 5.0 to 6.5 contribute most to the BEHC for PGA for the Davis Besse site. We also see that if earthquakes in the magnitude range 3.75 to 5 were included the BEHC would only be increased significantly in the range of 0.05g to about 0.25g.

TABLE 2.7.1

```
                        MOST IMPORTANT ZONES PER S-EXPERT
                                FOR DAVIS BESSE 1

SITE SOIL CATEGORY  ROCK

S-XPT  HOST           ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION
NUM.   ZONE             AT LOW PGA(0.125G)                                AT HIGH PGA(0.60G)
-----------------------------------------------------------------------------------------------------
 1  ZONE 19    ZONE ID: ZONE 19   ZONE 9    ZONE 10   ZONE 11      ZONE 19   ZONE 9    ZONE 10   ZONE 11
               % CONT.:      63.      21.        6.        6.          93.        7.        0.        0.
-----------------------------------------------------------------------------------------------------
 2  COMP. ZO   ZONE ID: ZONE 18   COMP. ZON ZONE 20   ZONE 27      ZONE 18   COMP. ZON ZONE 32   ZONE 20
               % CONT.:      67.      19.        9.        2.          65.      35.        0.        0.
-----------------------------------------------------------------------------------------------------
 3  ZONE 11    ZONE ID: ZONE 11   ZONE 13   ZONE 15   ZONE 12      ZONE 11   ZONE 13   COMP. ZON ZONE 15
               % CONT.:      95.       1.        1.        1.         100.        0.        0.        0.
-----------------------------------------------------------------------------------------------------
 4  ZONE 13    ZONE ID: ZONE  4   ZONE 27   ZONE  7   ZONE 16      ZONE  4   ZONE 27   ZONE  7   ZONE 13
               % CONT.:      34.      28.       24.        5.          42.      38.       15.        5.
-----------------------------------------------------------------------------------------------------
 5  COMP. ZO   ZONE ID: ZONE 12   ZONE  6   ZONE 15   ZONE 14      ZONE 12   ZONE 15   COMP. ZON ZONE  6
               % CONT.:      89.       8.        3.        0.          98.        2.        0.        0.
-----------------------------------------------------------------------------------------------------
 6  ZONE 9     ZONE ID: ZONE 9    ZONE 17   ZONE 10   ZONE 7       ZONE 9    ZONE 17   ZONE 10   COMP. ZON
               % CONT.:      87.       5.        2.        2.          99.        0.        0.        0.
-----------------------------------------------------------------------------------------------------
 7  ZONE 2 =   ZONE ID: ZONE 6    ZONE 11   ZONE 2 =  ZONE 5       ZONE 6    ZONE 2 =  ZONE 11   ZONE 5
               % CONT.:      62.      19.        7.        4.          73.      19.        8.        0.
-----------------------------------------------------------------------------------------------------
10  ZONE 26A   ZONE ID: ZONE 26A  ZONE 12A  ZONE 19 = ZONE  27     ZONE 26A  ZONE 19 = ZONE  27  ZONE   2
               % CONT.:      91.       3.        3.        1.          99.        1.        0.        0.
-----------------------------------------------------------------------------------------------------
11  ZONE  9    ZONE ID: ZONE  9   CZ = ZONE ZONE 10   ZONE  5      ZONE  9   CZ = ZONE ZONE 10   ZONE  5
               % CONT.:      84.       7.        4.        2.          98.        2.        0.        0.
-----------------------------------------------------------------------------------------------------
12  ZONE 4 =   ZONE ID: ZONE 31   ZONE 18   ZONE 17   ZONE 15      ZONE 15   ZONE 18   ZONE 17   ZONE 14
               % CONT.:      32.      14.       14.       14.          68.      29.        2.        1.
-----------------------------------------------------------------------------------------------------
13  CZ 15      ZONE ID: CZ 15     ZONE  7   ZONE  5   ZONE  6      CZ 15     ZONE  5   ZONE  7   ZONE  3
               % CONT.:      61.      21.       15.        2.          95.        2.        2.        0.
-----------------------------------------------------------------------------------------------------
```

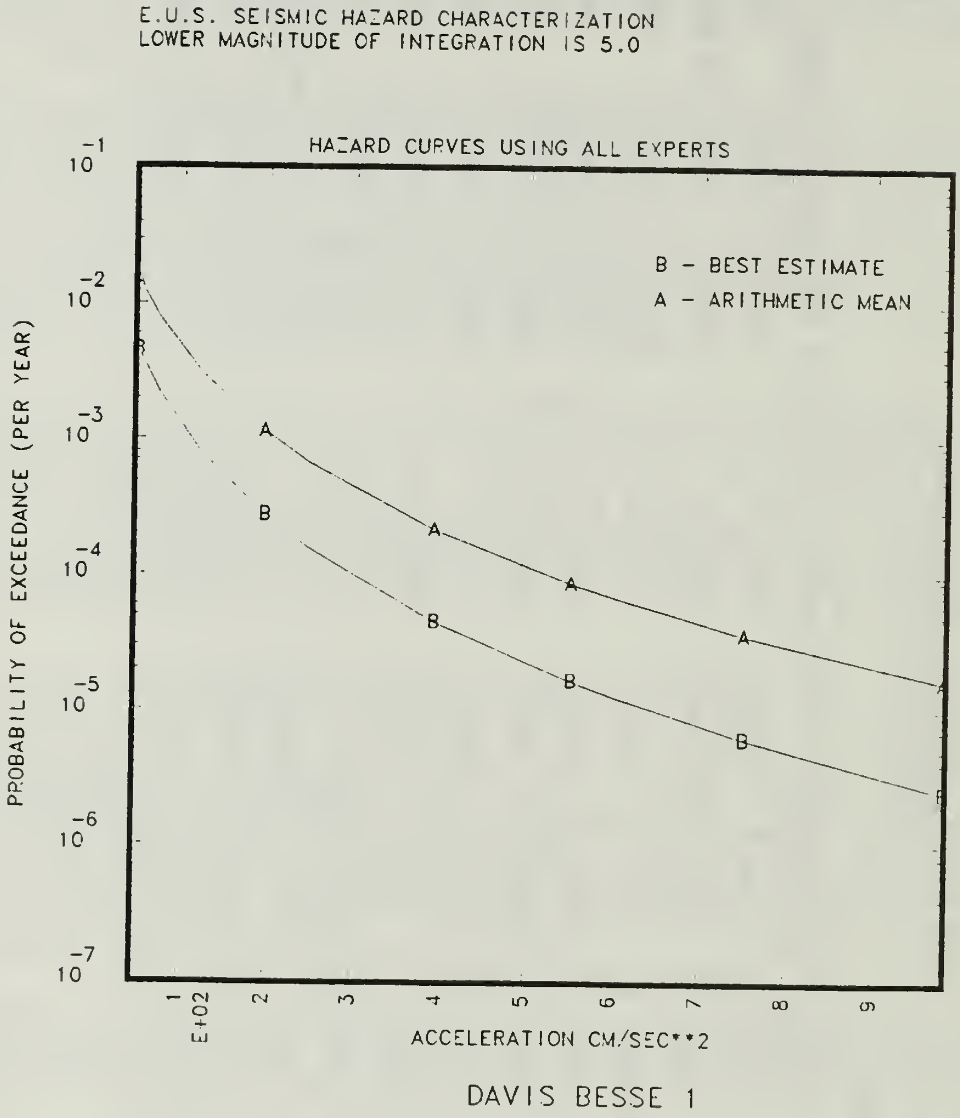


Figure 2.7.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Davis Besse site.

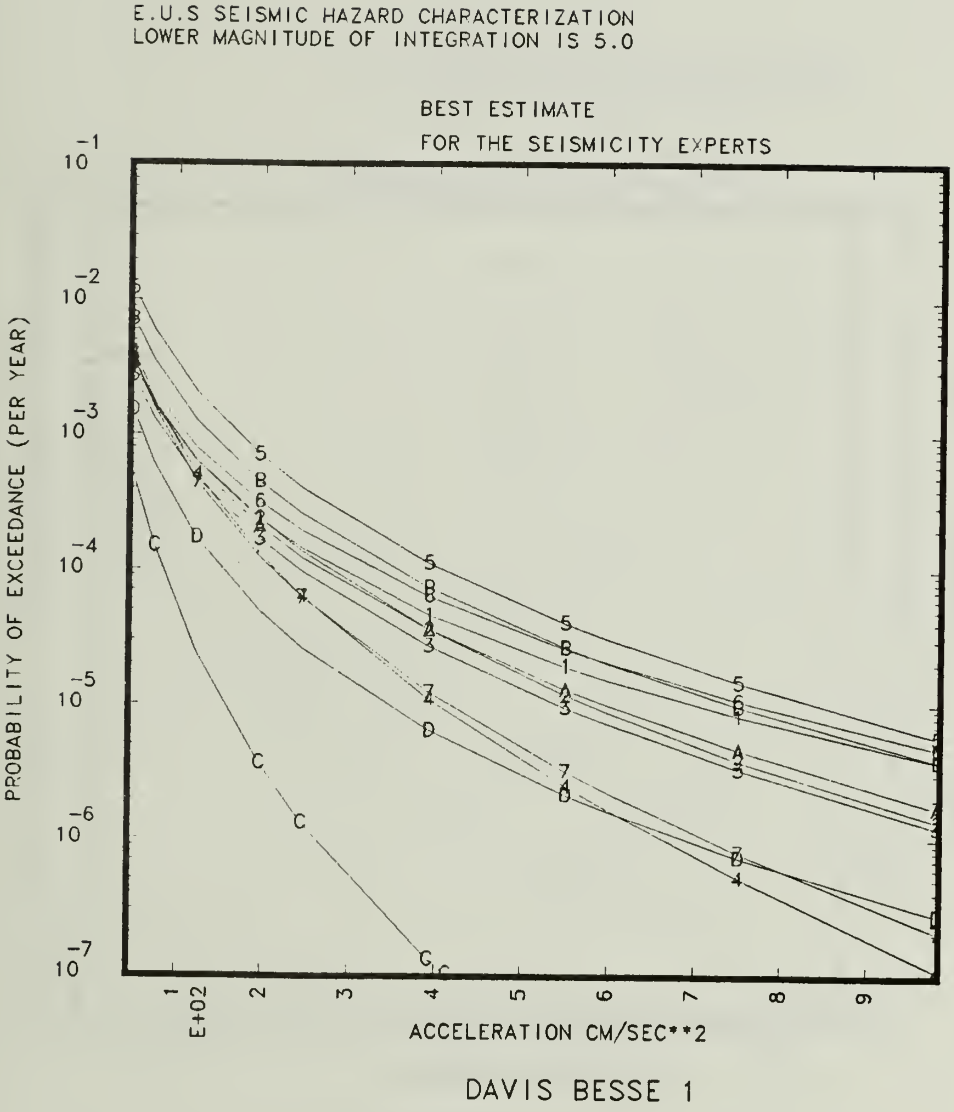


Figure 2.7.2 BEHCs per S-Expert combined over all G-Experts for the Davis Besse site. Plot symbols given in Table 2.0.

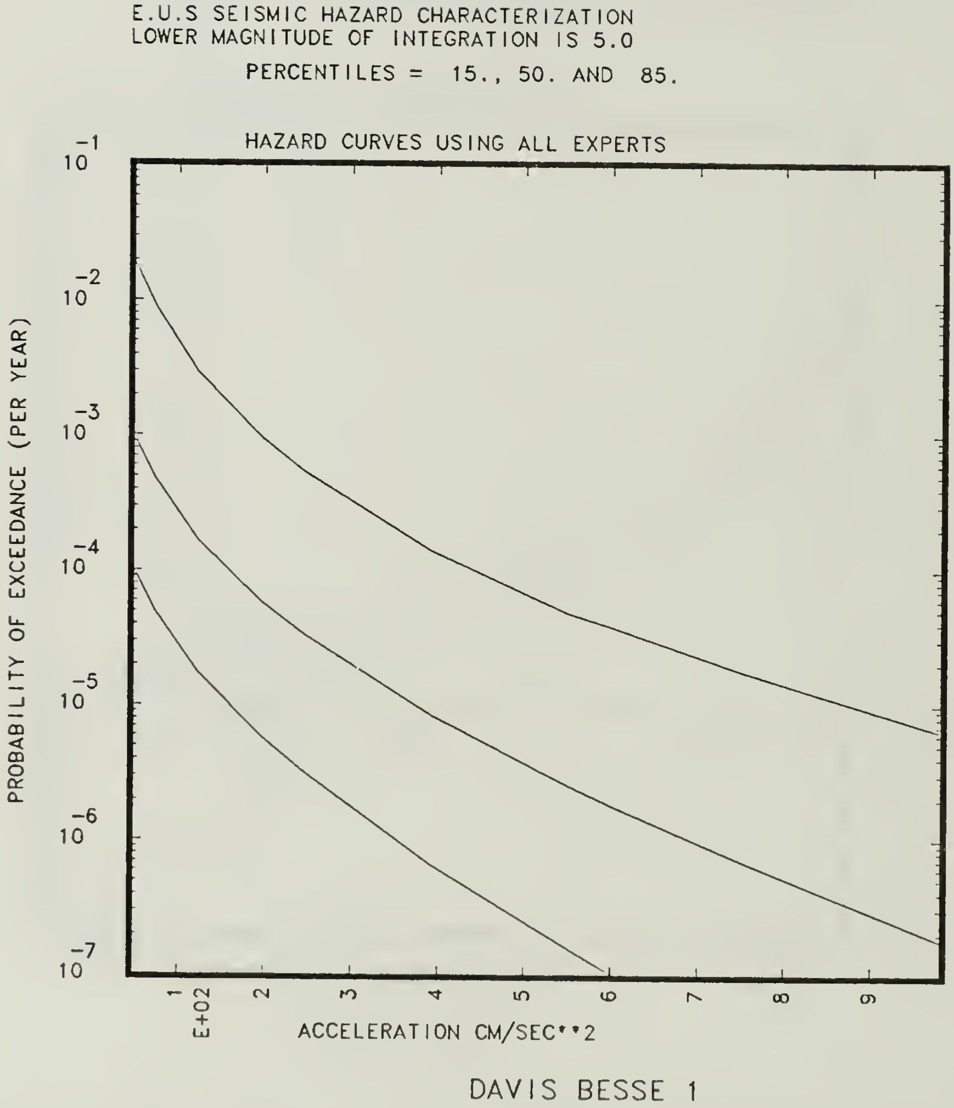
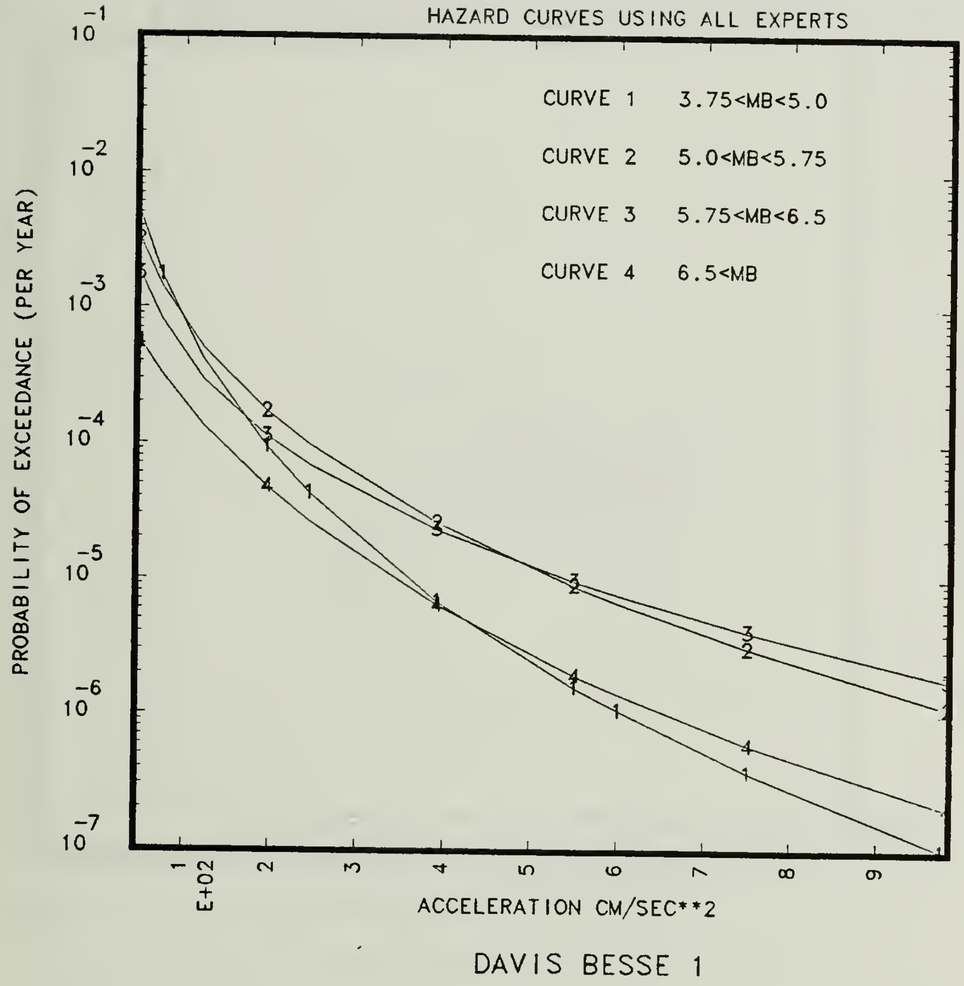


Figure 2.7.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Davis Besse site.



igure 2.7.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Davis Besse site.

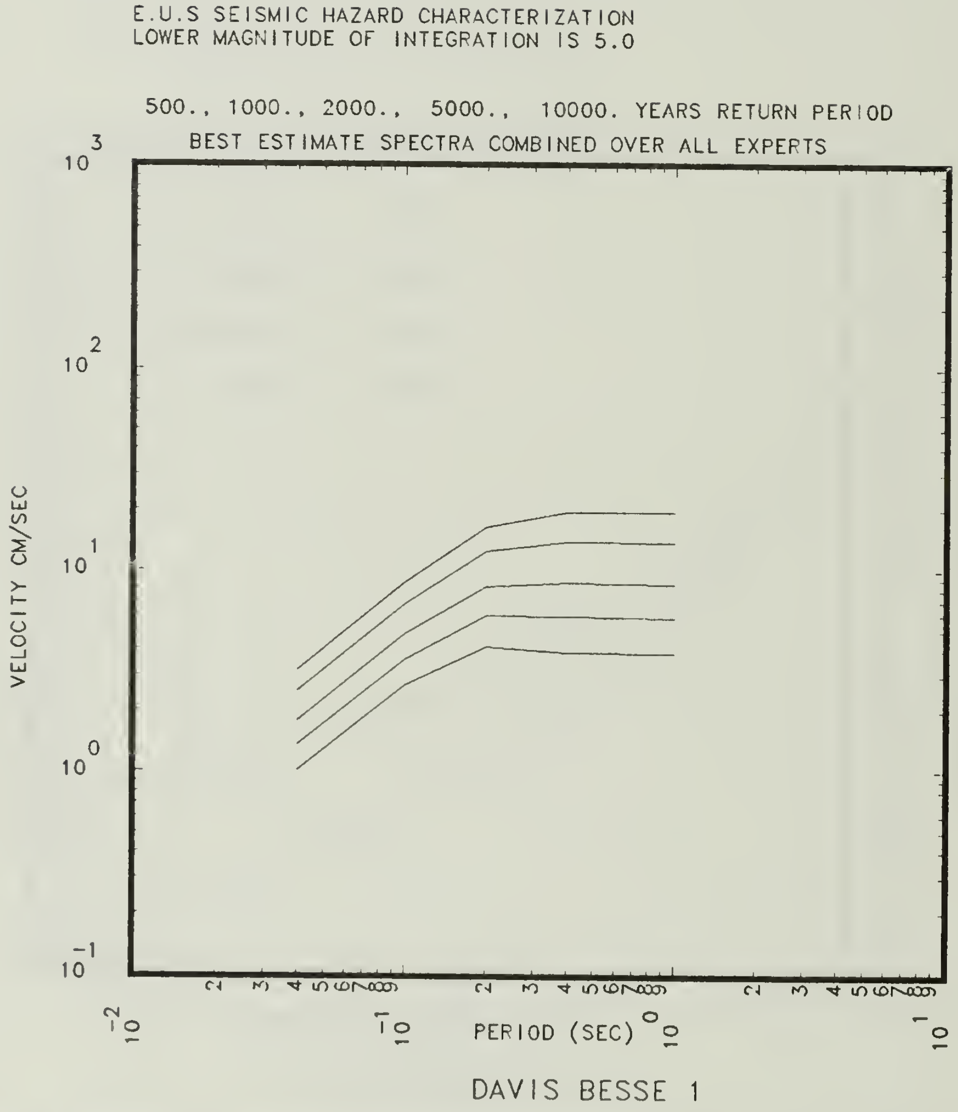


Figure 2.7.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Davis Besse site.

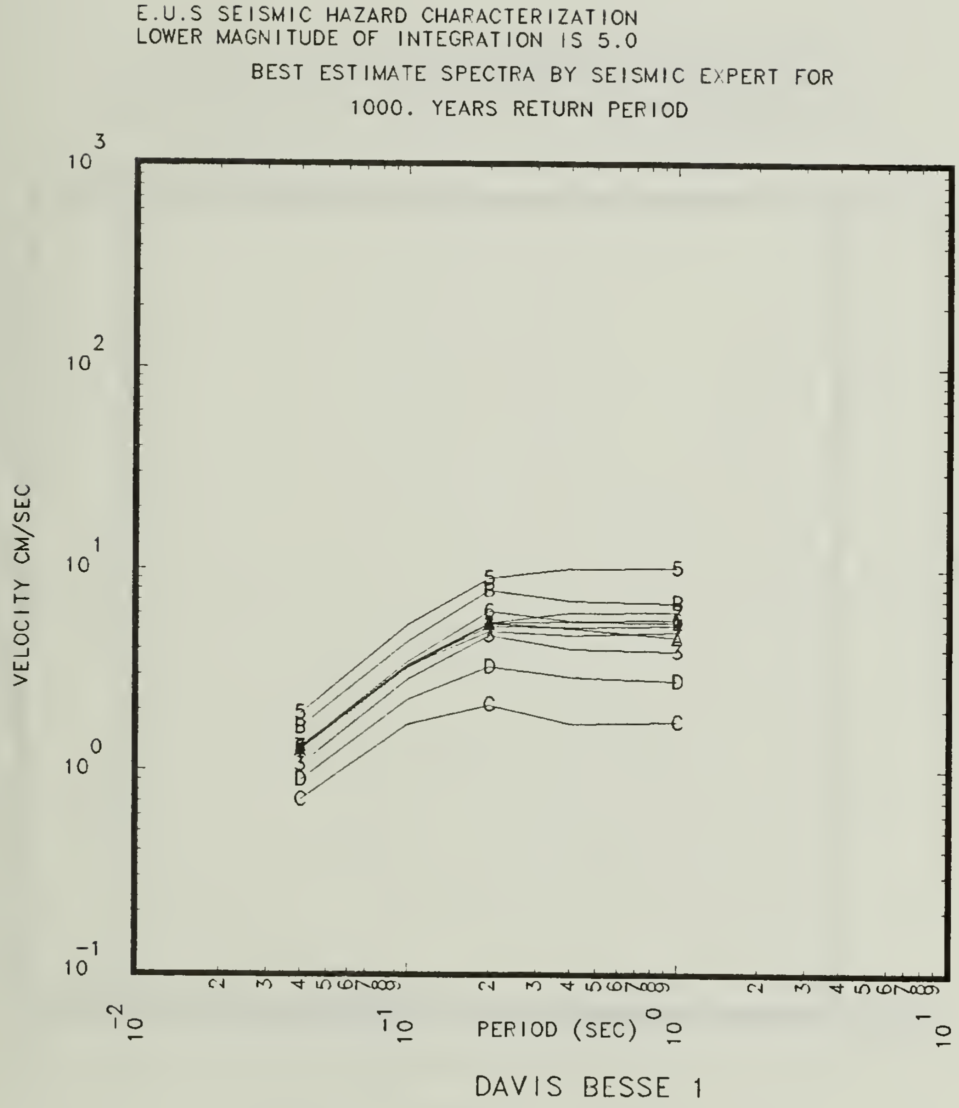


Figure 2.7.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Davis Besse site. Plot symbols are given in Table 2.0.

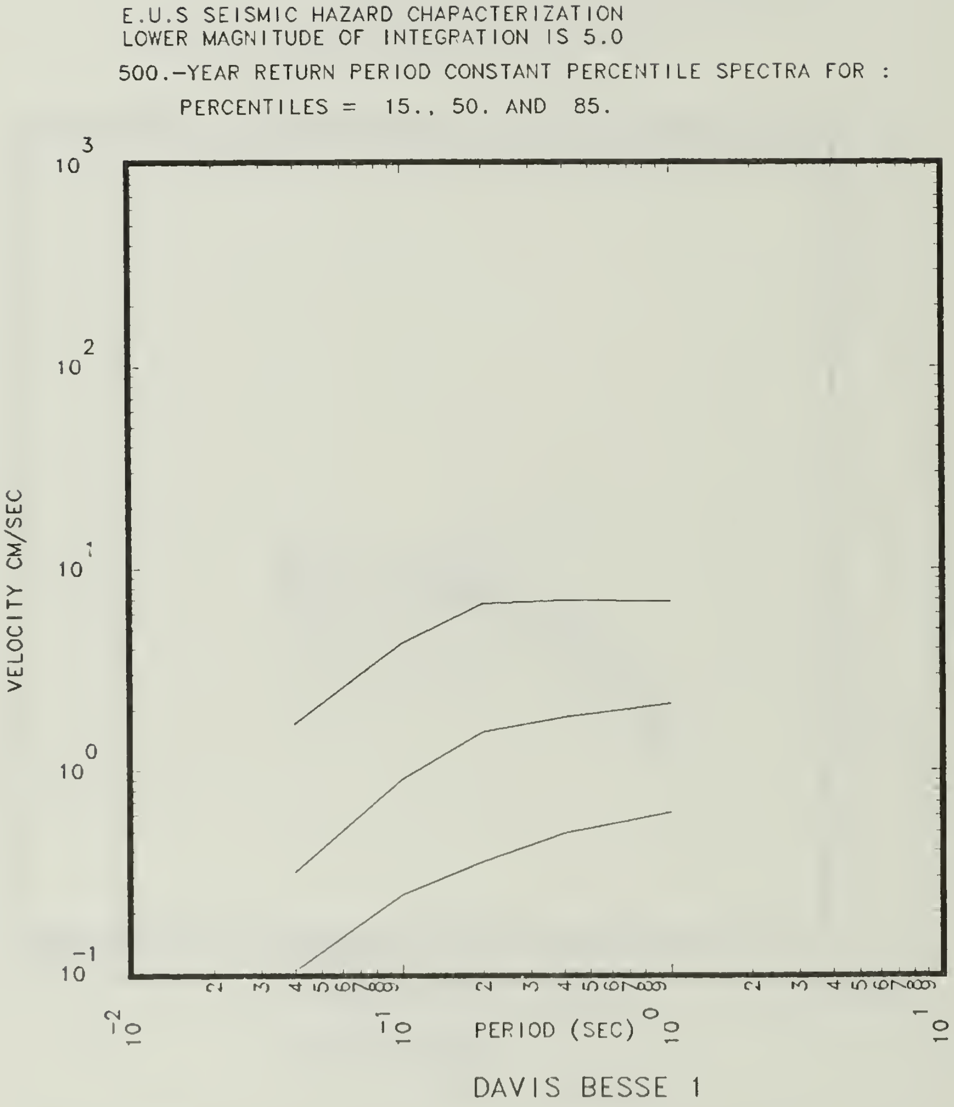
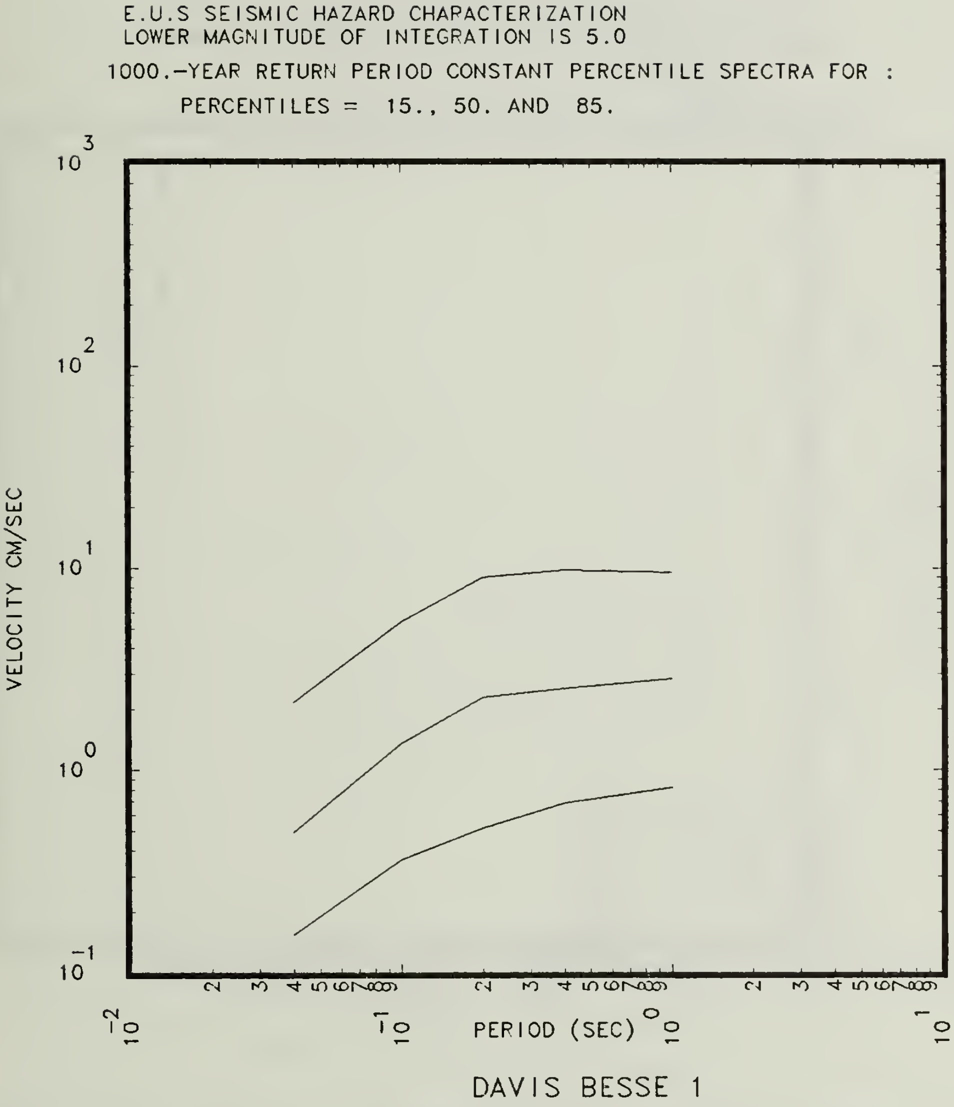


Figure 2.7.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Davis Besse site.



E.U.S SEISMIC HAZARD CHARACTERIZATION
LOWER MAGNITUDE OF INTEGRATION IS 5.0
1000.-YEAR RETURN PERIOD CONSTANT PERCENTILE SPECTRA FOR :
PERCENTILES = 15., 50. AND 85.

DAVIS BESSE 1

Figure 2.7.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Davis Besse site.

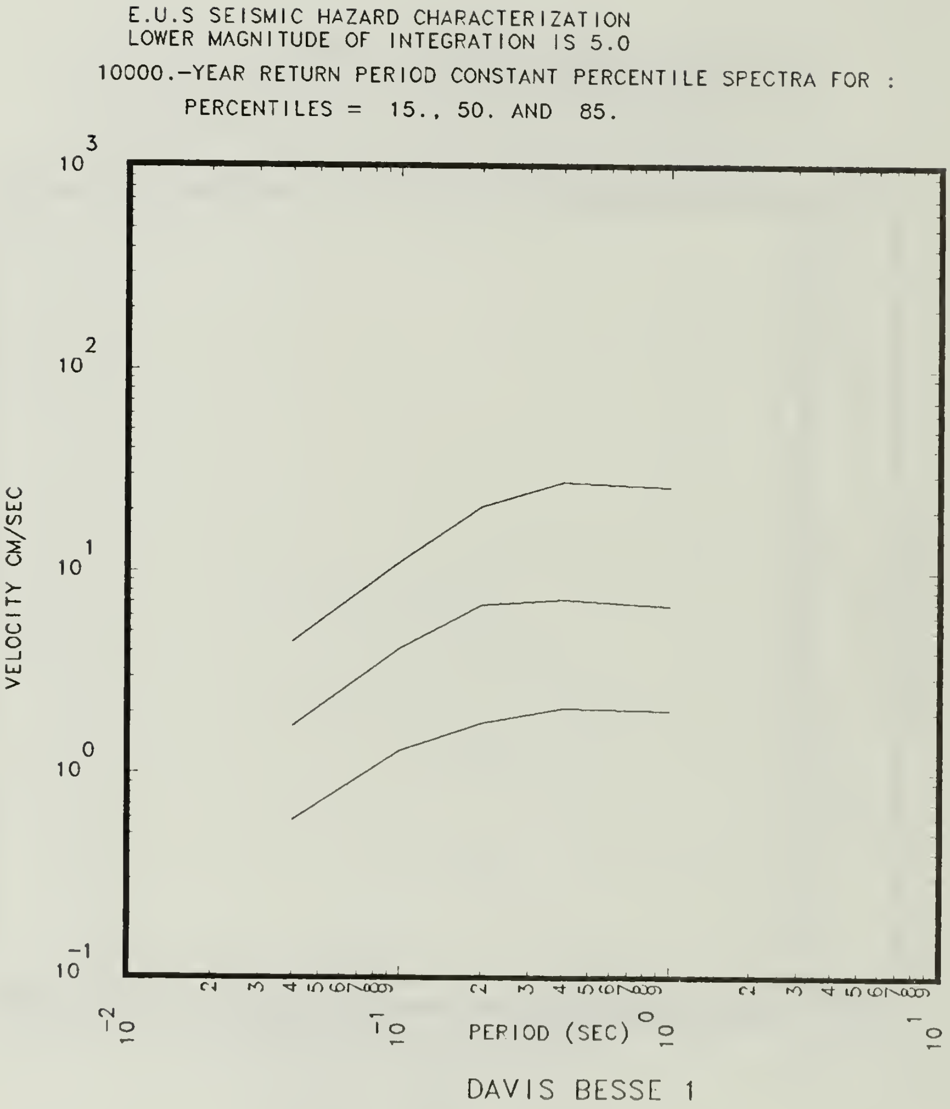


Figure 2.7.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Davis Besse site.

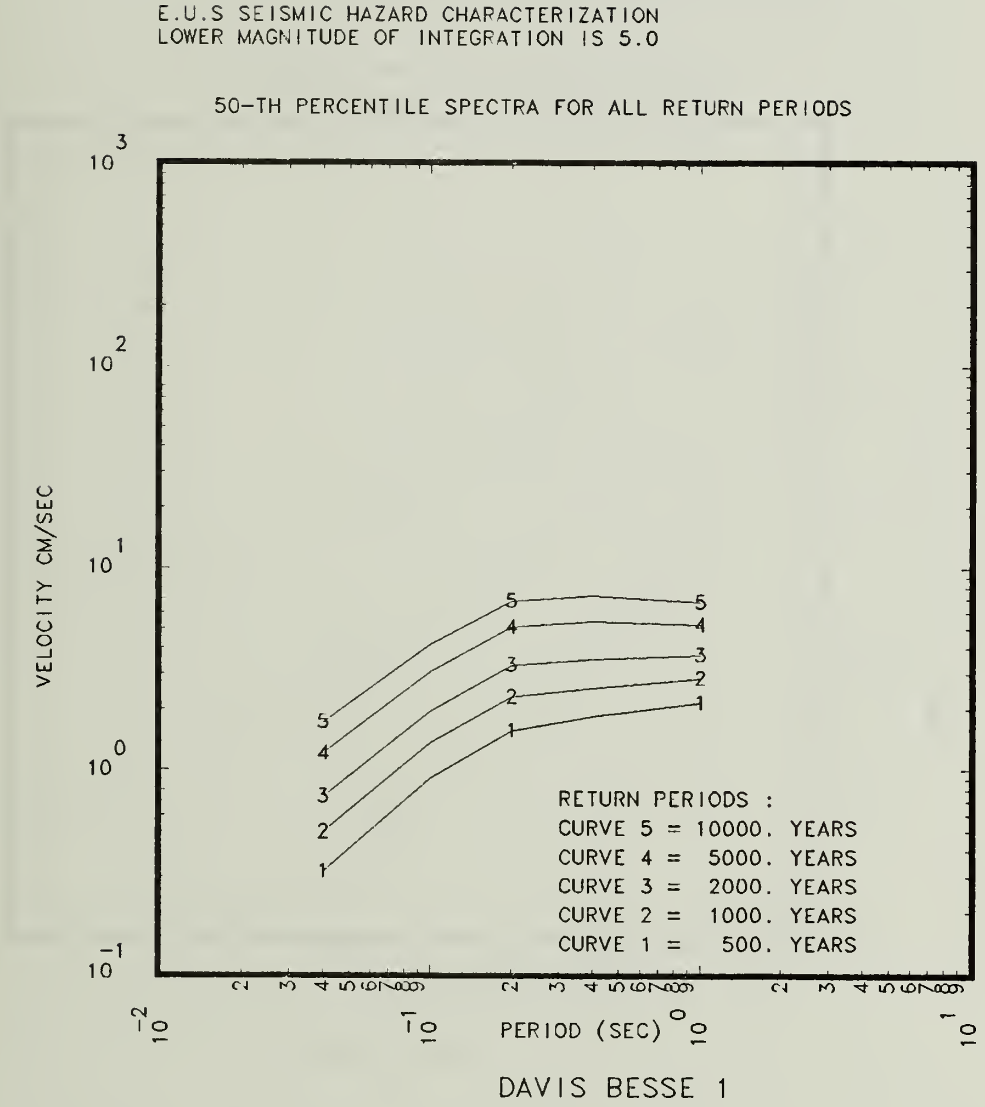


Figure 2.7.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Davis Besse site.

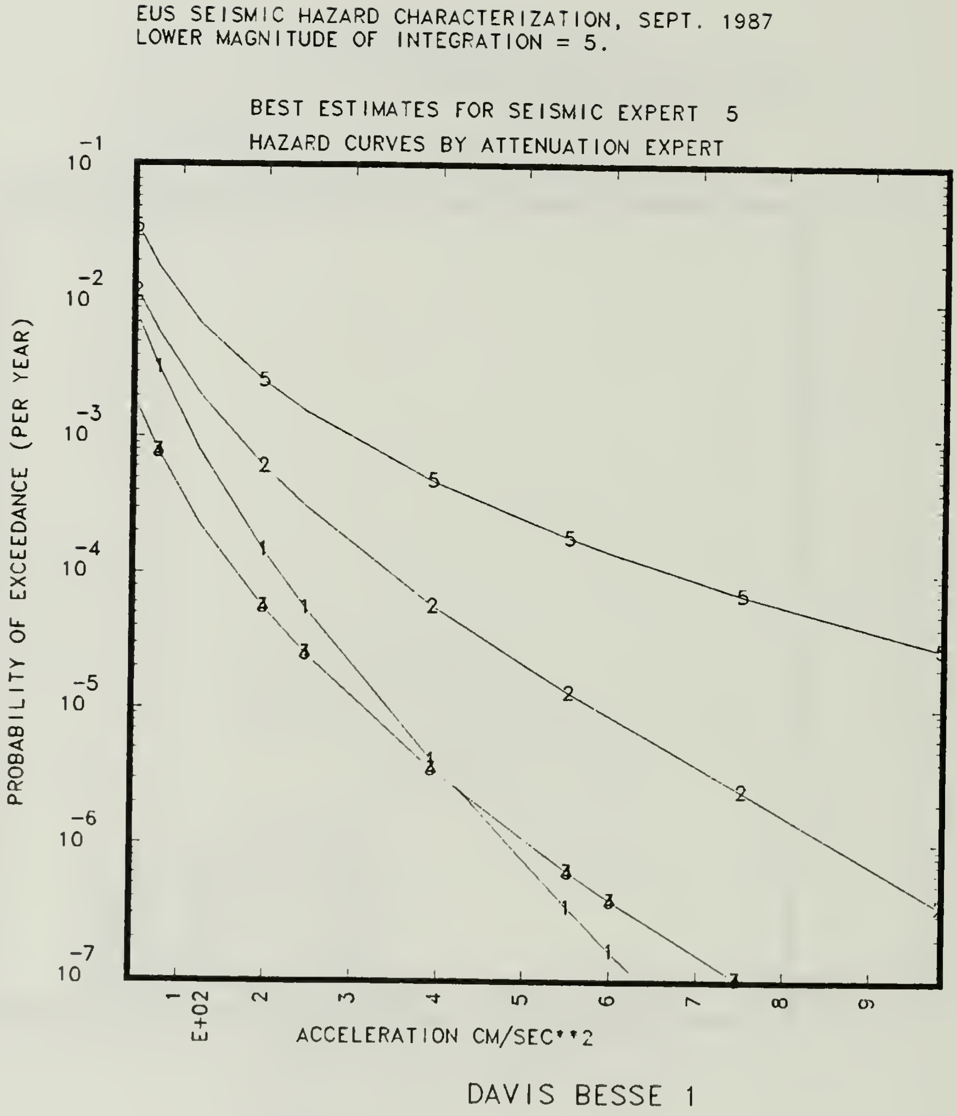


Figure 2.7.11 The BEHCs per G-Expert for S-Expert 5's zonation and seismicity parameters for the Davis Besse site.

2.8 DRESDEN

The Dresden site is a rock site and it is represented by the symbol "8" on Fig. 1.1. Table 2.8.1 and Figs. 2.8.1 through 2.8.10 give the basic results for the Dresden site.

It can be seen from Fig. 1.1 that the Dresden site is very near the Braidwood site, thus there are only very minor differences in the results between the two sites, hence, there is no need to repeat the discussions given in Section 2.3.

TABLE 2.8.1

MOST IMPORTANT ZONES PER S-EXPERT FOR DRESDEN 2&3

SITE SOIL CATEGORY ROCK

S-XPT NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 19	ZONE ID:	ZONE 19	ZONE 11	ZONE 9	ZONE 10	ZONE 19	ZONE 9	ZONE 11	ZONE 10
		% CONT.:	29.	28.	27.	15.	54.	23.	19.	4.
2	ZONE 21	ZONE ID:	ZONE 18	ZONE 21	ZONE 20	COMP. ZON	ZONE 18	ZONE 21	COMP. ZON	ZONE 20
		% CONT.:	60.	18.	16.	4.	80.	14.	4.	2.
3	ZONE 15	ZONE ID:	ZONE 15	ZONE 12	ZONE 13	ZONE 16	ZONE 15	ZONE 13	ZONE 12	ZONE 16
		% CONT.:	40.	24.	17.	10.	78.	8.	7.	5.
4	ZONE 6	ZONE ID:	ZONE 6	ZONE 4	ZONE 5	ZONE 3	ZONE 6	ZONE 4	ZONE 5	ZONE 3
		% CONT.:	43.	43.	10.	2.	69.	29.	2.	0.
5	COMP. ZO	ZONE ID:	ZONE 15	ZONE 12	ZONE 14	COMP. ZON	ZONE 15	COMP. ZON	ZONE 14	ZONE 12
		% CONT.:	69.	13.	12.	2.	97.	2.	0.	0.
6	ZONE 22	ZONE ID:	ZONE 17	ZONE 22	ZONE 18	ZONE 9	ZONE 17	ZONE 22	ZONE 18	ZONE 9
		% CONT.:	59.	28.	6.	6.	49.	46.	3.	1.
7	ZONE 34	ZONE ID:	ZONE 6	ZONE 34	ZONE 5	ZONE 2 =	ZONE 6	ZONE 34	ZONE 5	ZONE 2 =
		% CONT.:	75.	14.	9.	1.	85.	13.	1.	0.
10	ZONE 26A	ZONE ID:	ZONE 26A	ZONE 19 =	ZONE 12A	ZONE 13	ZONE 26A	ZONE 19 =	ZONE 12A	ZONE 13
		% CONT.:	61.	19.	13.	6.	92.	7.	1.	0.
11	CZ = ZON	ZONE ID:	ZONE 10	CZ = ZONE	ZONE 11	ZONE 9	ZONE 10	CZ = ZONE	ZONE 11	ZONE 9
		% CONT.:	60.	32.	7.	1.	51.	47.	2.	0.
12	ZONE 4 =	ZONE ID:	ZONE 13	ZONE 15	ZONE 14	ZONE 31A	ZONE 15	ZONE 14	ZONE 13	ZONE 5
		% CONT.:	41.	38.	18.	1.	94.	4.	2.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 5	ZONE 6	ZONE 4	CZ 15	ZONE 5	ZONE 6	ZONE 1
		% CONT.:	50.	35.	13.	1.	84.	16.	0.	0.

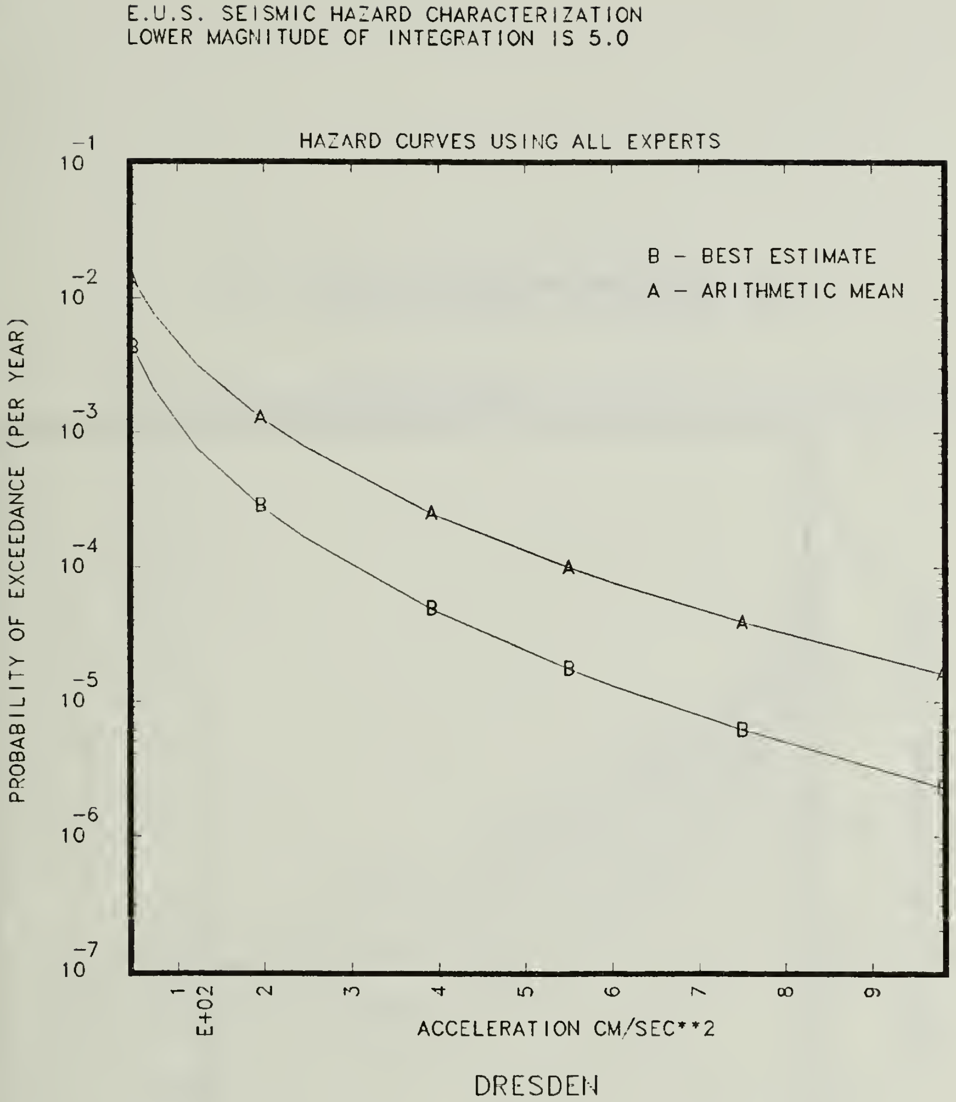


Figure 2.8.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Dresden site.

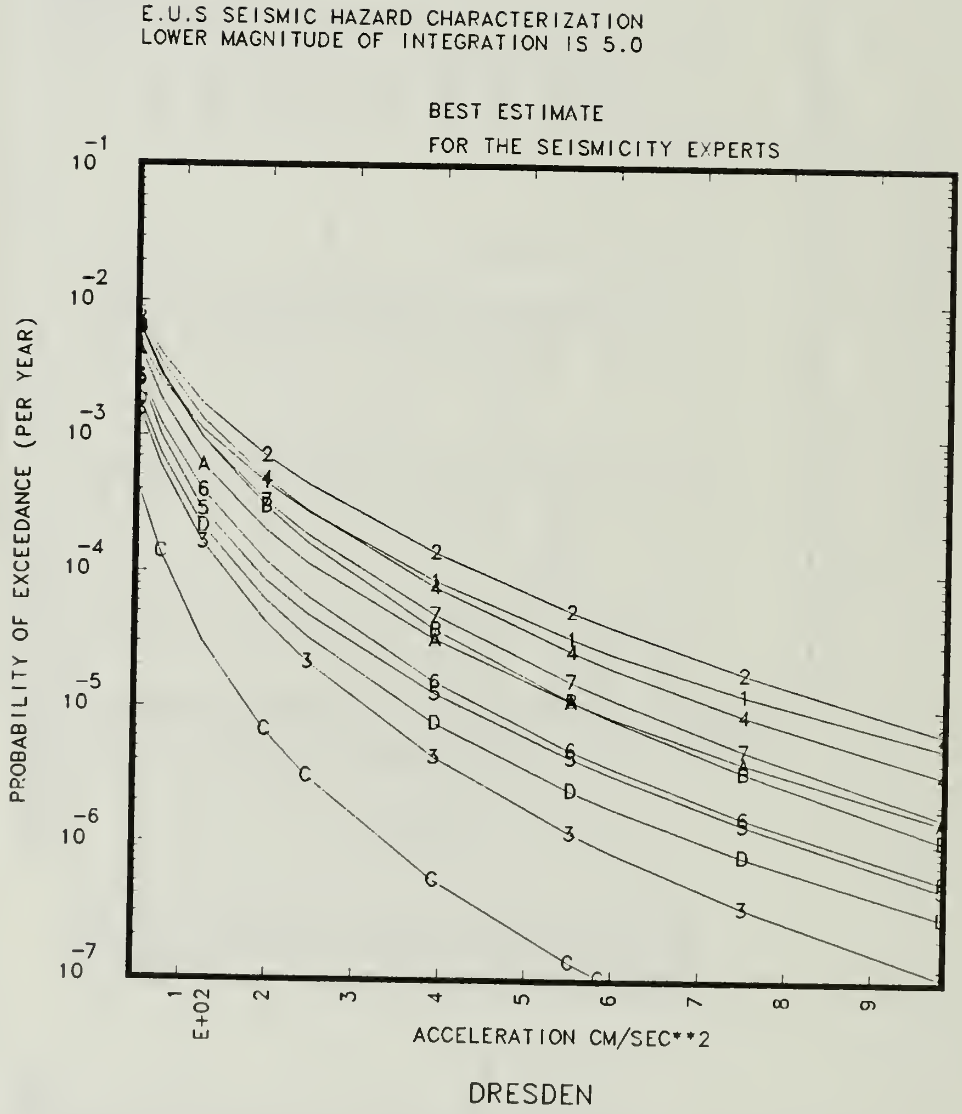


Figure 2.8.2 BEHCs per S-Expert combined over all G-Experts for the Dresden site. Plot symbols given in Table 2.0.

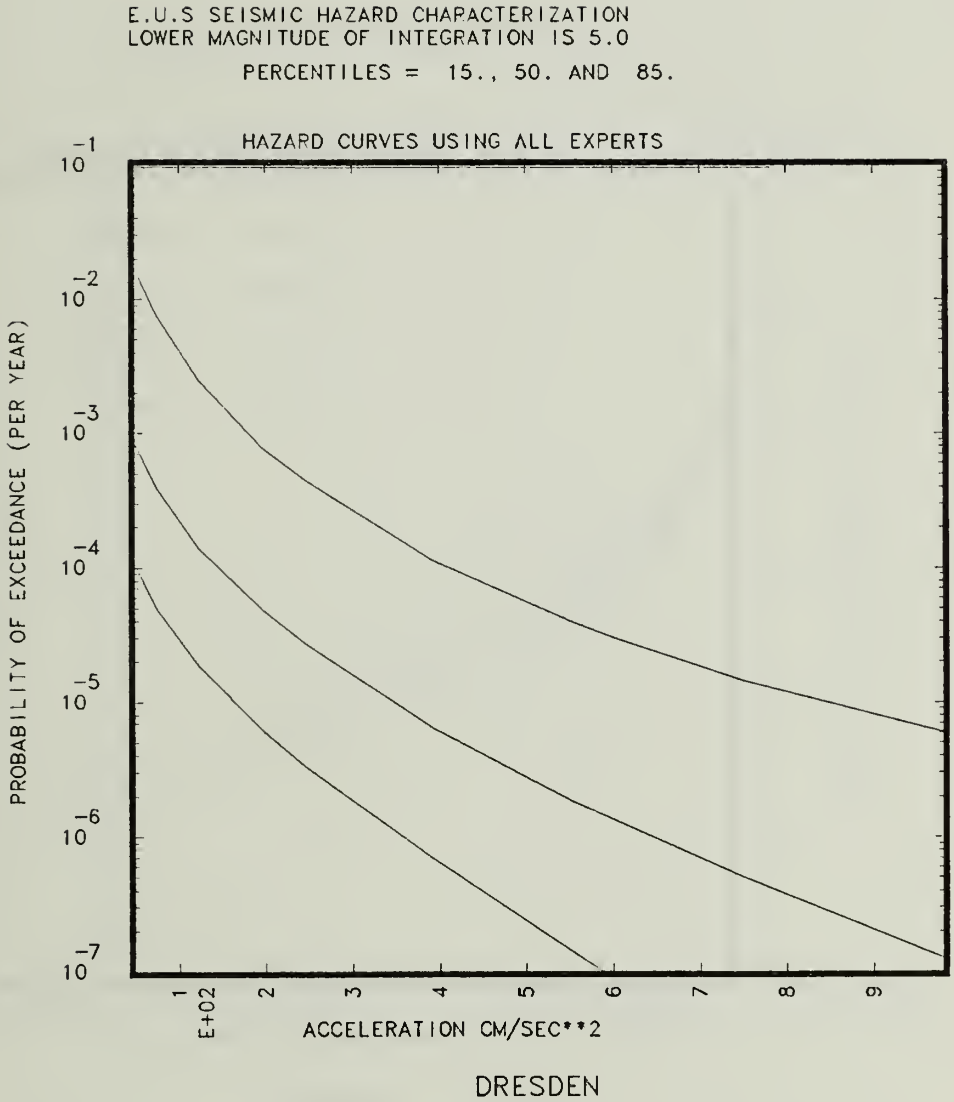


Figure 2.8.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Dresden site.

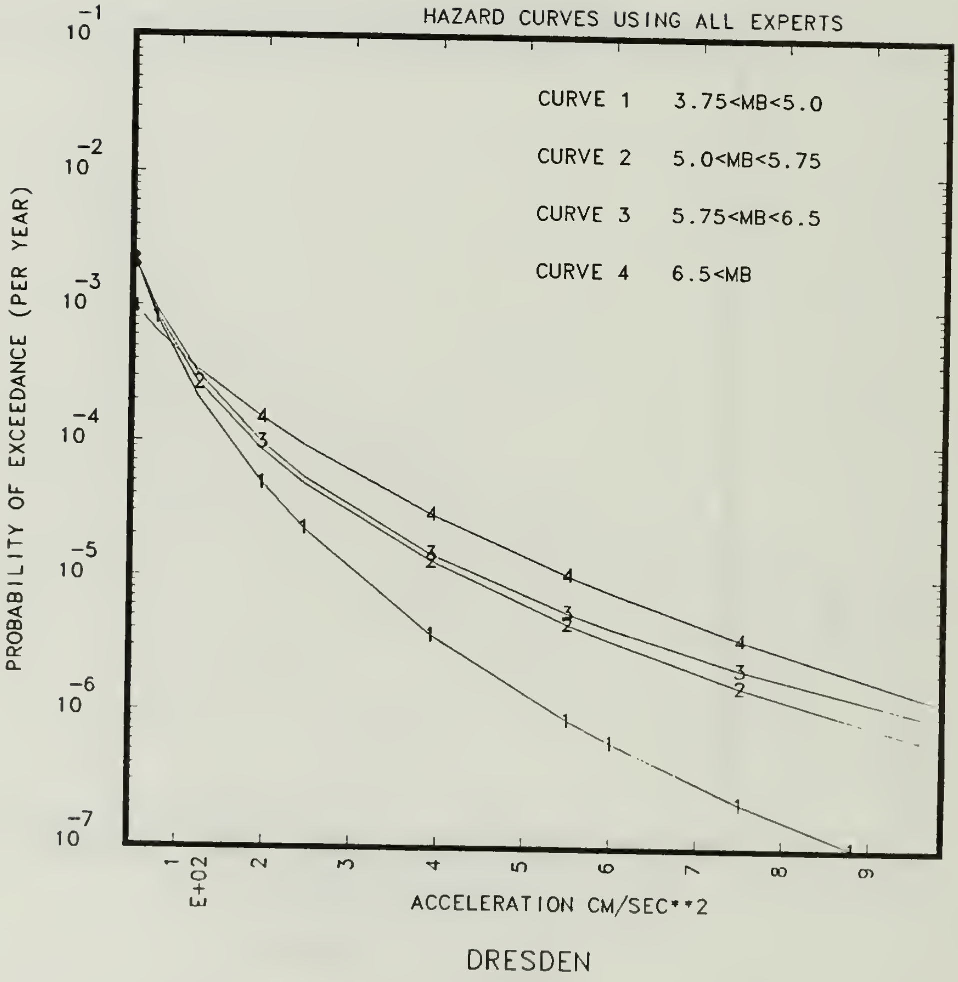


Figure 2.8.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Dresden site.

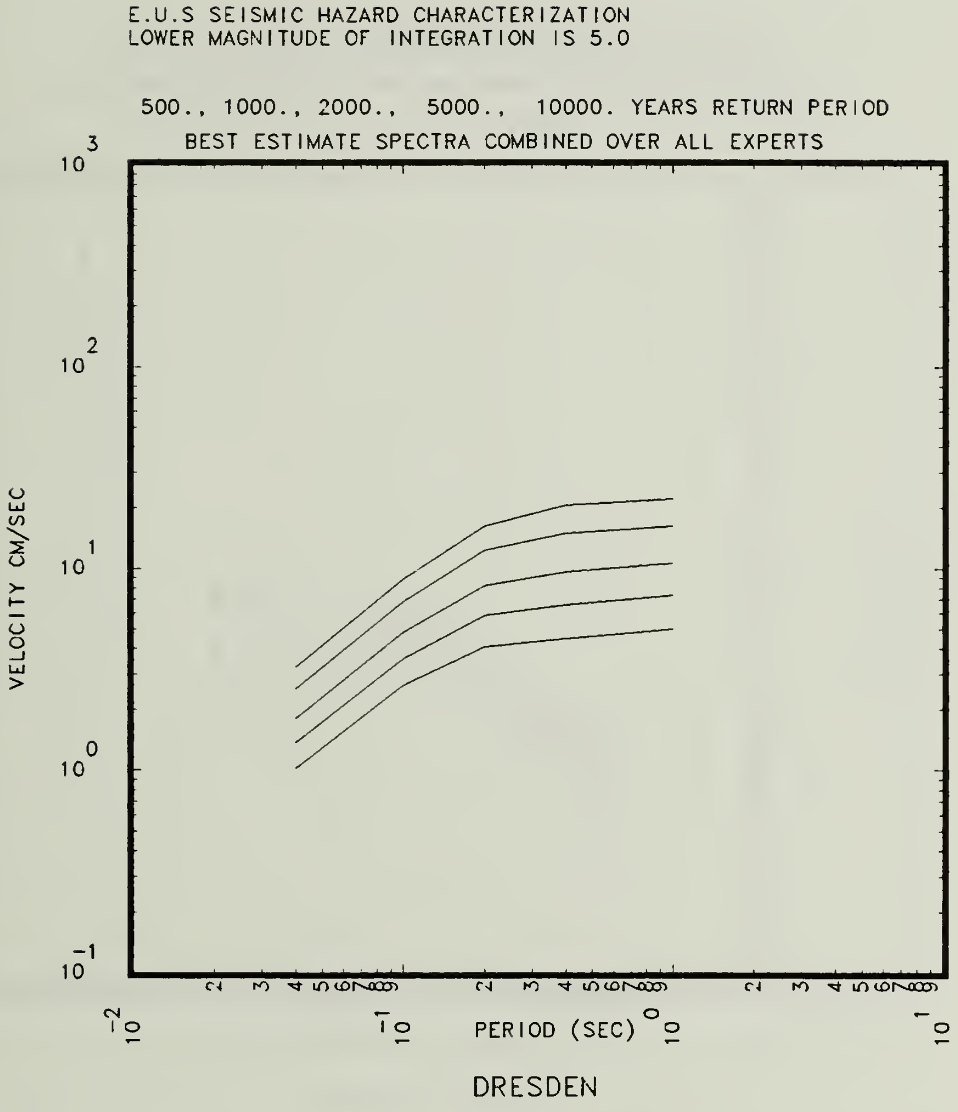


Figure 2.8.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Dresden site.

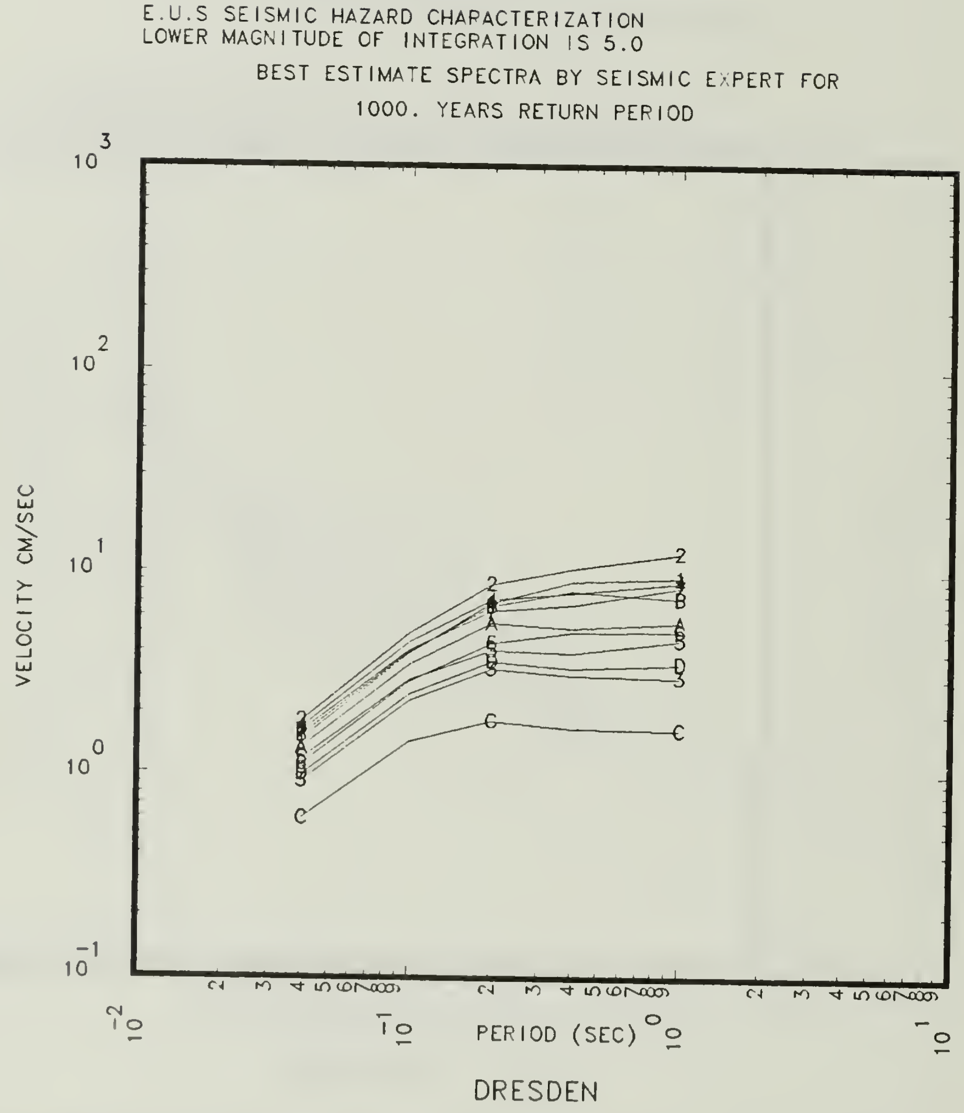


Figure 2.8.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Dresden site. Plot symbols are given in Table 2.0.

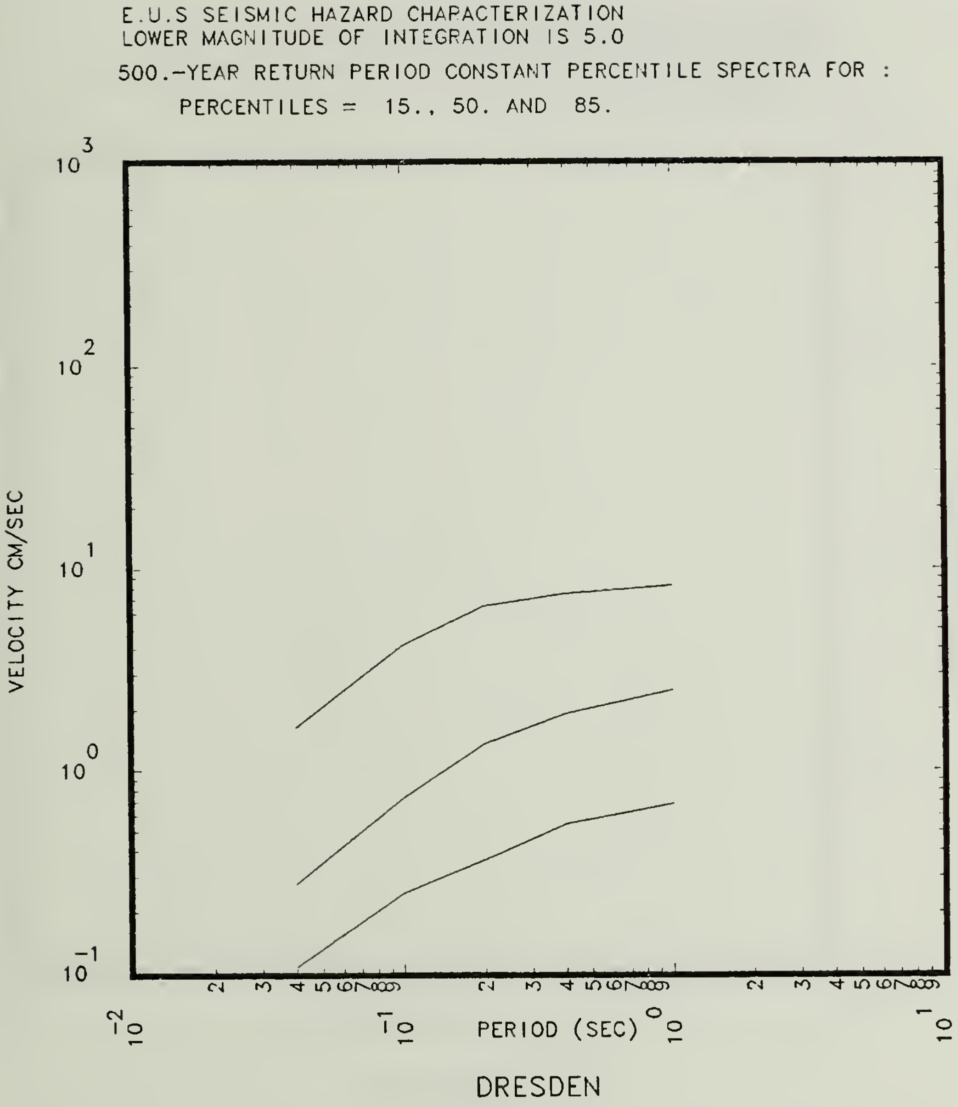


Figure 2.8.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Dresden site.

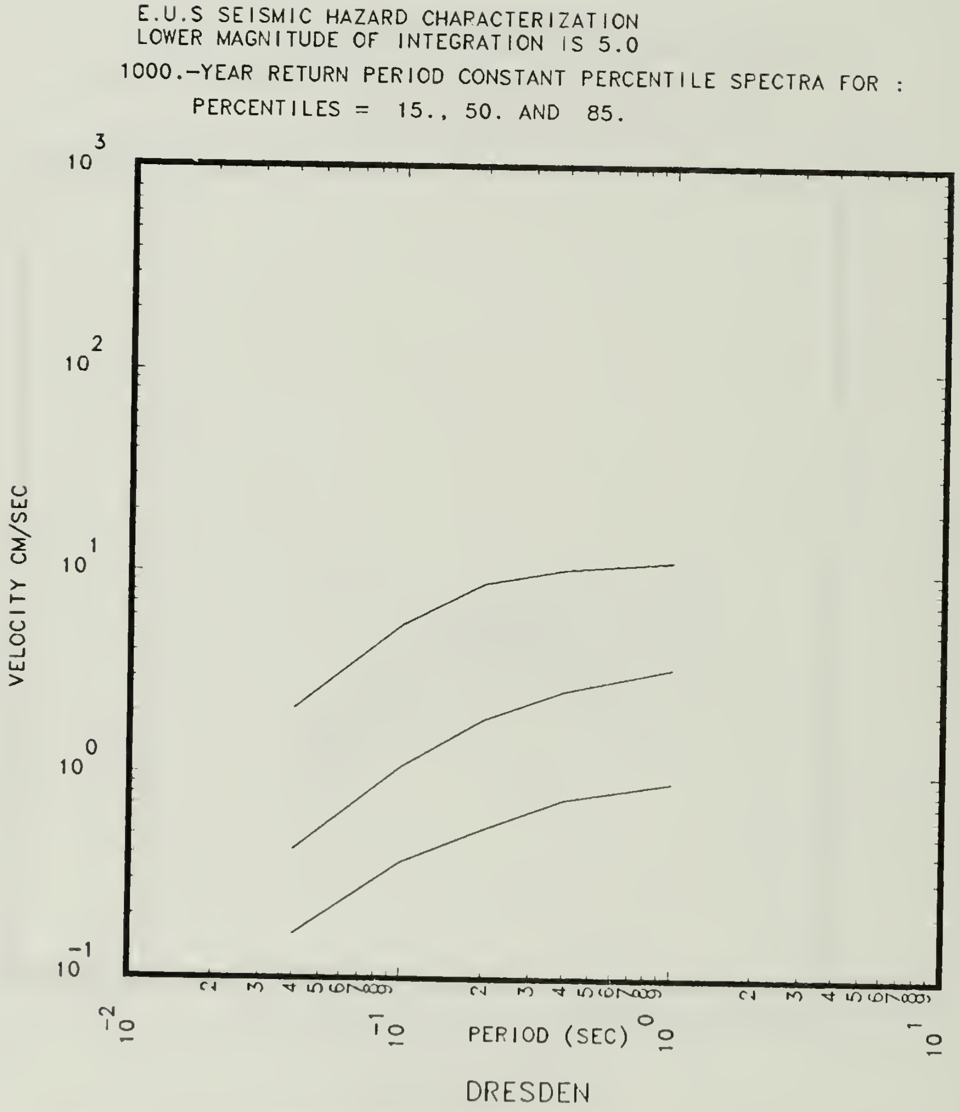


Figure 2.8.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Dresden site.

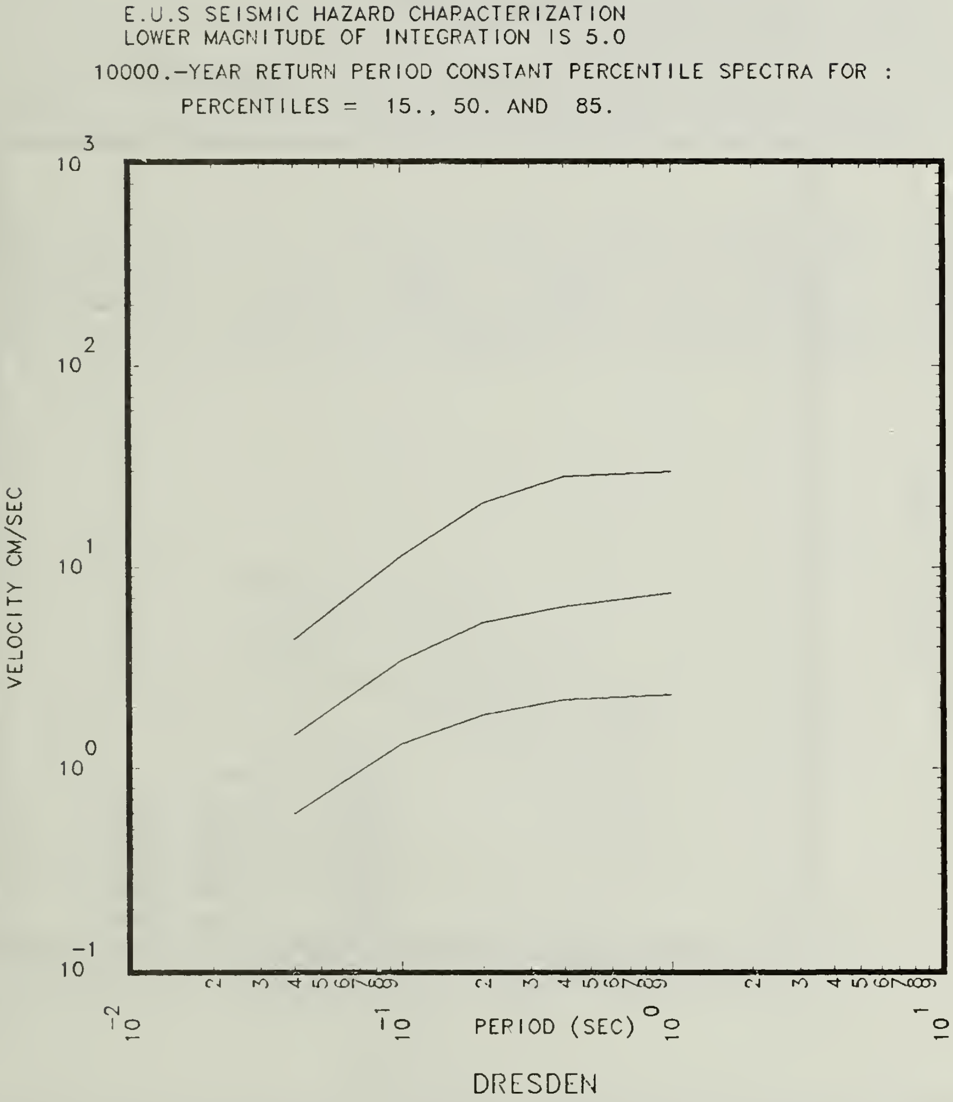


Figure 2.8.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Dresden site.

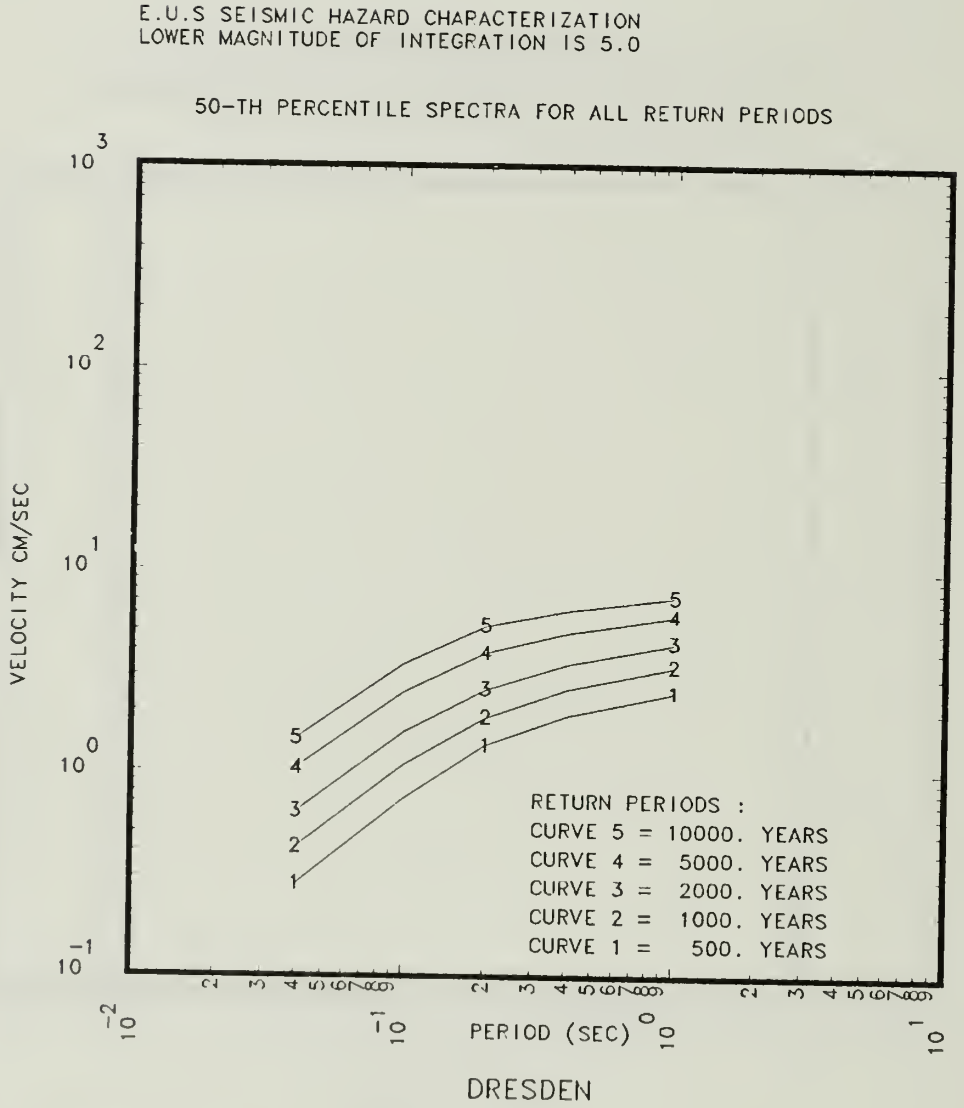


Figure 2.8.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Dresden site.

2.9 FERMI

The Fermi site is a rock site and it is represented by the symbol "9" in Fig. 1.1. Table 2.9.1 and Figs. 2.9.1 through 2.9.10 give the basic results for the Fermi site.

It can be seen from Fig. 1.1 that the Fermi site is near the Davis Besse site, however, there are some interesting differences in results between the two sites. This spread between the AMHC and the BEHC is about the same at the Fermi site as at the Davis Besse site, however, the hazard as measured by the two estimators is lower at the Fermi site. We see by comparing Fig. 2.9.2 to 2.7.2 that BEHCs for S-Experts 5 and 11 is lower at Fermi than at Davis Besse. If the maps in Appendix B are examined it is easy to see why this is the case. For S-Expert 5 is it easy to see that Fermi is much further from S-Expert 5's zone 12 which contributes most to the BEHC for PGA for S-Expert 5. Similarly it is also seen that the Fermi site is very near the border of S-Expert 11's zone 9 whereas the Davis Besse site was in the "middle" of the zone.

The discussion of Section 2.7 relative to the spread between the G-Experts' BEHCs per S-Expert holds for the Fermi site except for S-Experts 5 and 11. The spread between the G-Experts' BEHCs is slightly increased for S-Experts 5 and 11's input for the Fermi site as compared to the Davis Besse site, but the changes are not very significant.

TABLE 2.9.1

MOST IMPORTANT ZONES PER S-EXPERT FOR FERMI

SITE SOIL CATEGORY ROCK

S-XPT NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION							
			AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 19	ZONE ID:	ZONE 19	ZONE 9	ZONE 11	ZONE 10	ZONE 19	ZONE 9	ZONE 15	ZONE 11
		% CONT.:	56.	23.	7.	6.	88.	10.	2.	0.
2	COMP. ZO	ZONE ID:	ZONE 18	COMP. ZON	ZONE 20	ZONE 27	ZONE 18	COMP. ZON	ZONE 32	ZONE 20
		% CONT.:	65.	21.	9.	2.	59.	40.	1.	0.
3	ZONE 11	ZONE ID:	ZONE 11	ZONE 15	ZONE 13	ZONE 12	ZONE 11	ZONE 15	ZONE 13	COMP. ZON
		% CONT.:	94.	3.	1.	1.	100.	0.	0.	0.
4	ZONE 13	ZONE ID:	ZONE 4	ZONE 27	ZONE 7	ZONE 16	ZONE 4	ZONE 27	ZONE 7	ZONE 13
		% CONT.:	39.	24.	21.	7.	58.	23.	10.	8.
5	COMP. ZO	ZONE ID:	ZONE 12	ZONE 6	ZONE 15	COMP. ZON	ZONE 12	ZONE 15	COMP. ZON	ZONE 6
		% CONT.:	80.	14.	5.	1.	95.	4.	1.	0.
6	ZONE 9	ZONE ID:	ZONE 9	ZONE 17	ZONE 7	ZONE 10	ZONE 9	COMP. ZON	ZONE 17	ZONE 10
		% CONT.:	85.	5.	2.	2.	99.	0.	0.	0.
7	ZONE 2 =	ZONE ID:	ZONE 6	ZONE 11	ZONE 2 =	ZONE 5	ZONE 6	ZONE 2 =	ZONE 11	ZONE 5
		% CONT.:	68.	13.	9.	4.	76.	21.	2.	0.
10	ZONE 26A	ZONE ID:	ZONE 26A	ZONE 27	ZONE 12A	ZONE 19 =	ZONE 26A	ZONE 27	ZONE 19 =	ZONE 3
		% CONT.:	85.	5.	4.	3.	96.	3.	1.	0.
11	CZ = ZON	ZONE ID:	ZONE 9	CZ = ZONE	ZONE 10	ZONE 5	ZONE 9	CZ = ZONE	ZONE 10	ZONE 5
		% CONT.:	66.	23.	6.	2.	74.	26.	0.	0.
12	ZONE 4 =	ZONE ID:	ZONE 31	ZONE 31A	ZONE 15	ZONE 17	ZONE 15	ZONE 18	ZONE 17	ZONE 14
		% CONT.:	40.	16.	14.	10.	93.	6.	0.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 5	ZONE 7	ZONE 6	CZ 15	ZONE 5	ZONE 7	ZONE 3
		% CONT.:	69.	16.	12.	2.	97.	2.	0.	0.

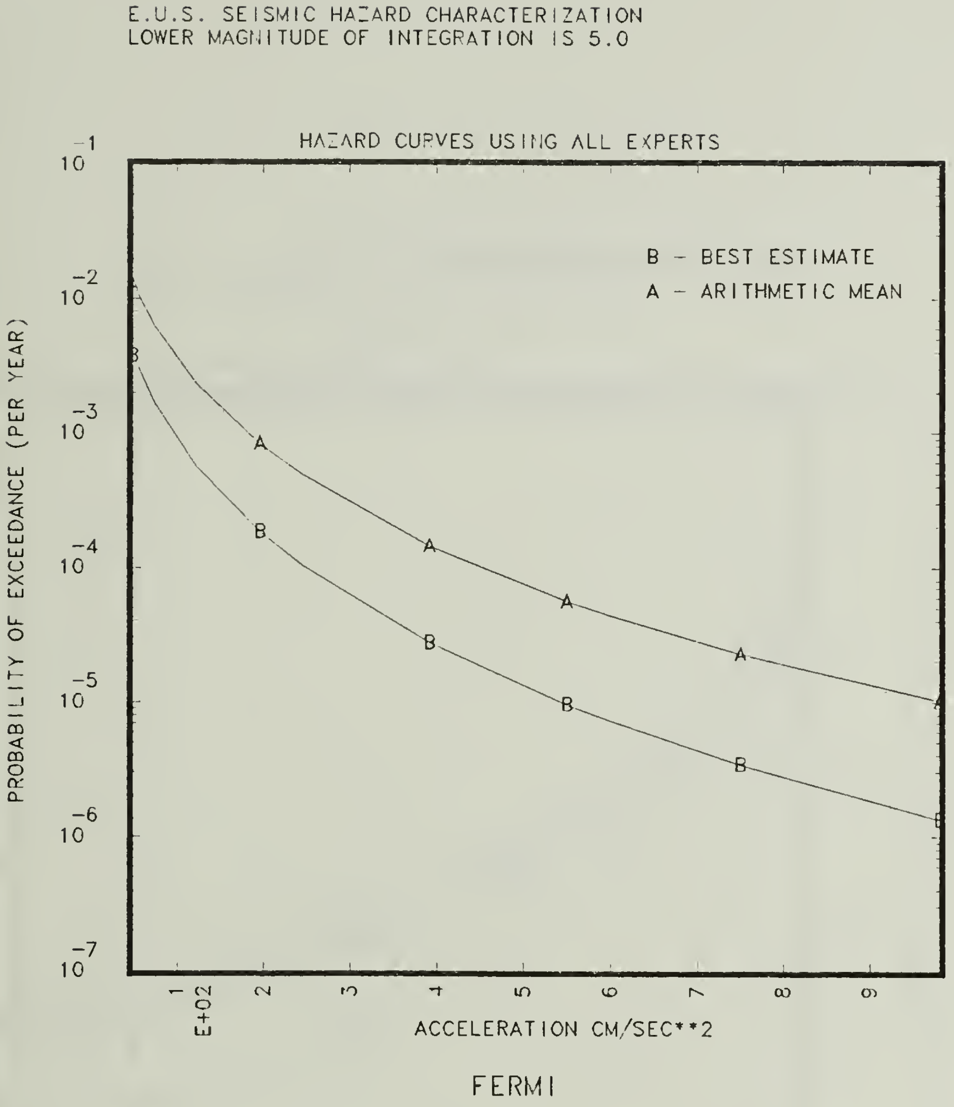


Figure 2.9.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Fermi site.

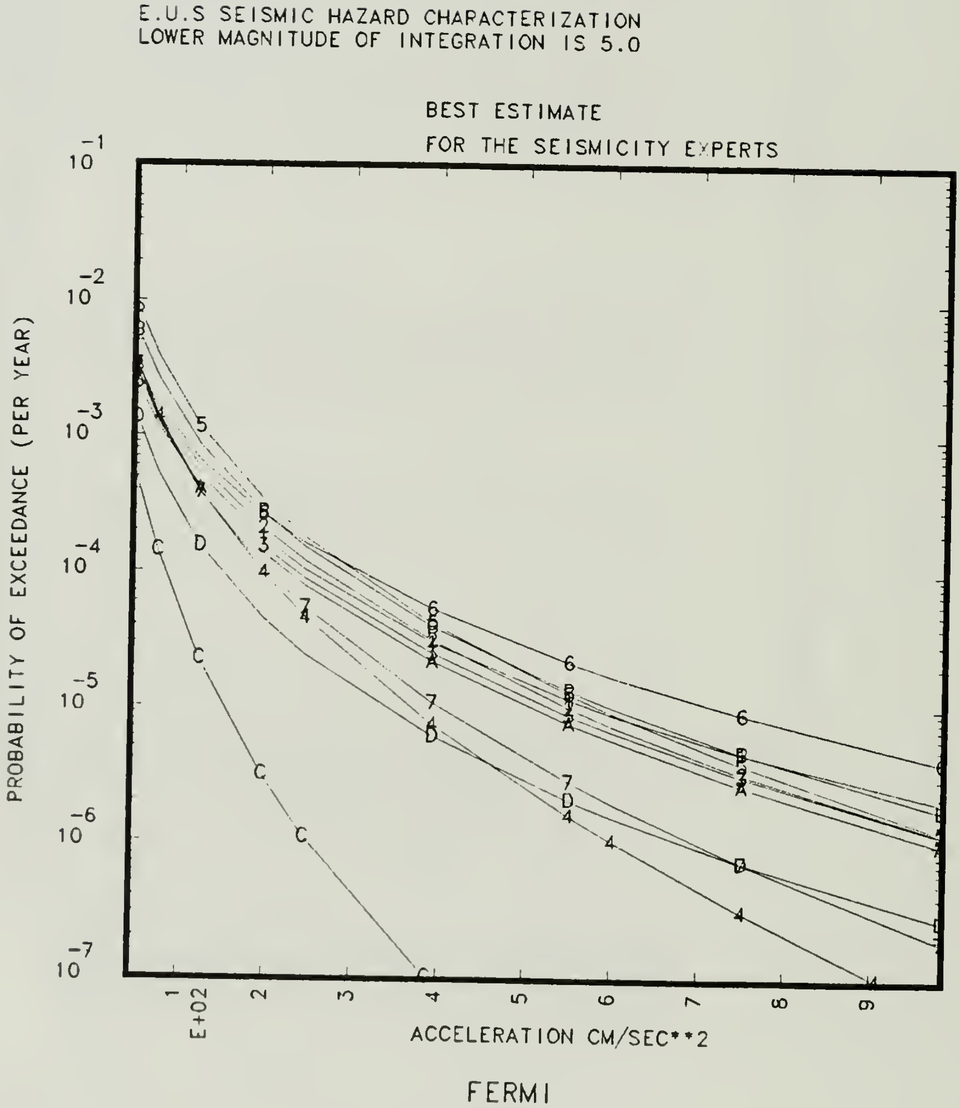


Figure 2.9.2 BEHCs per S-Expert combined over all G-Experts for the Fermi site. Plot symbols given in Table 2.0.

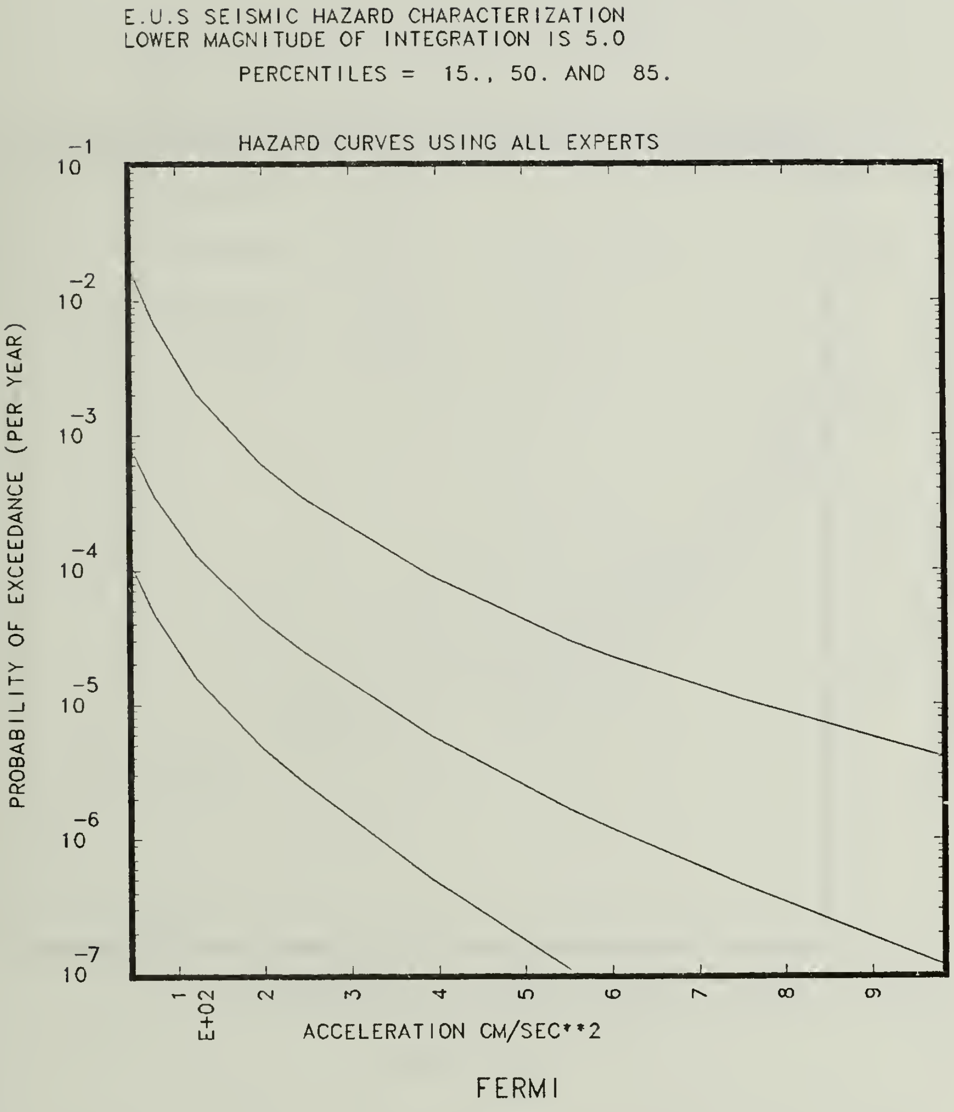


Figure 2.9.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Fermi site.

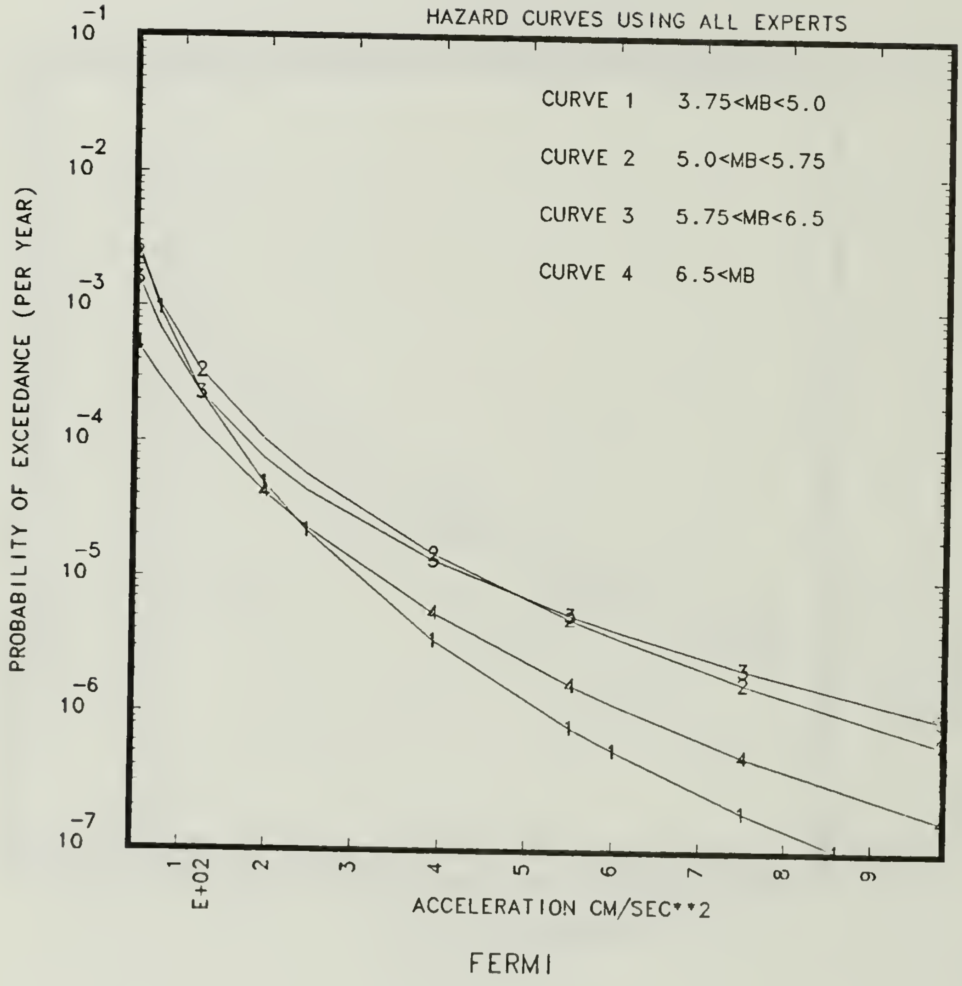


Figure 2.9.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Fermi site.

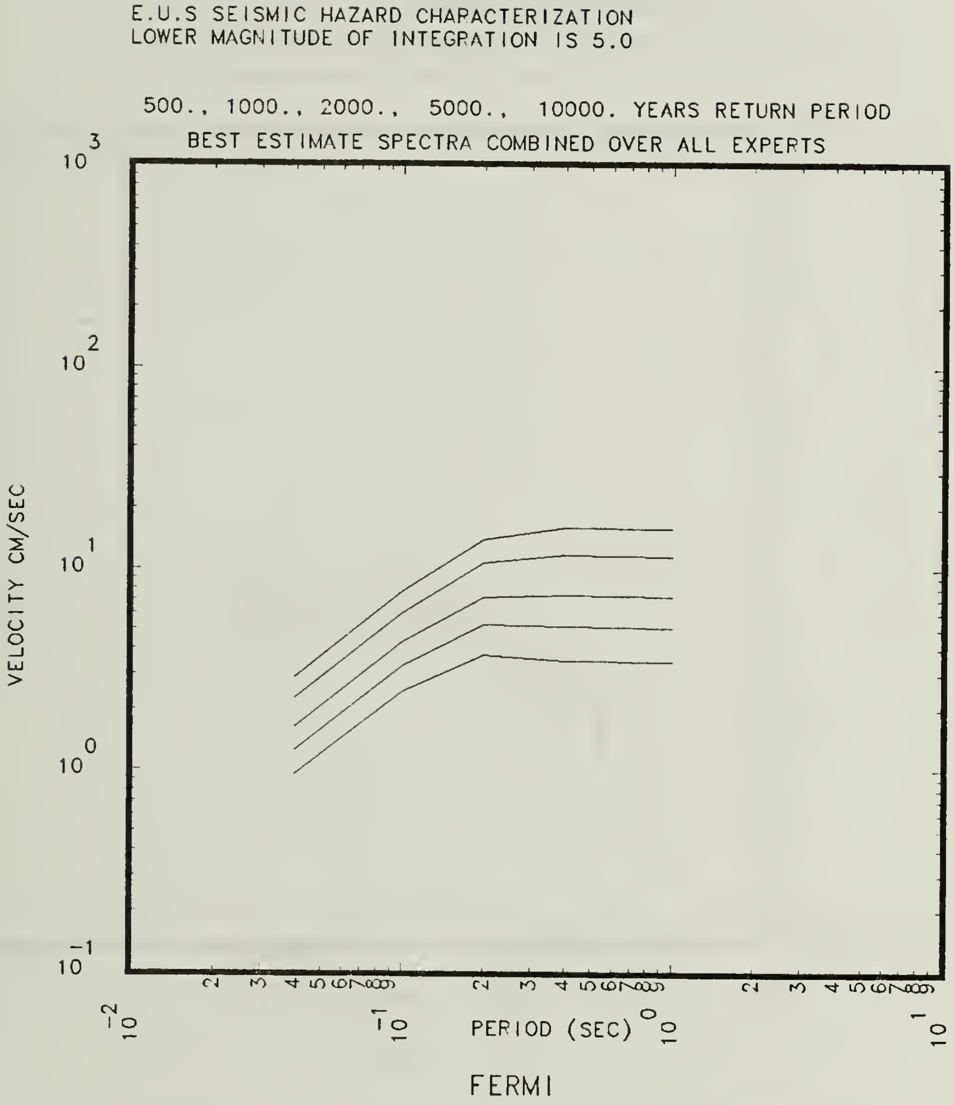


Figure 2.9.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Fermi site.

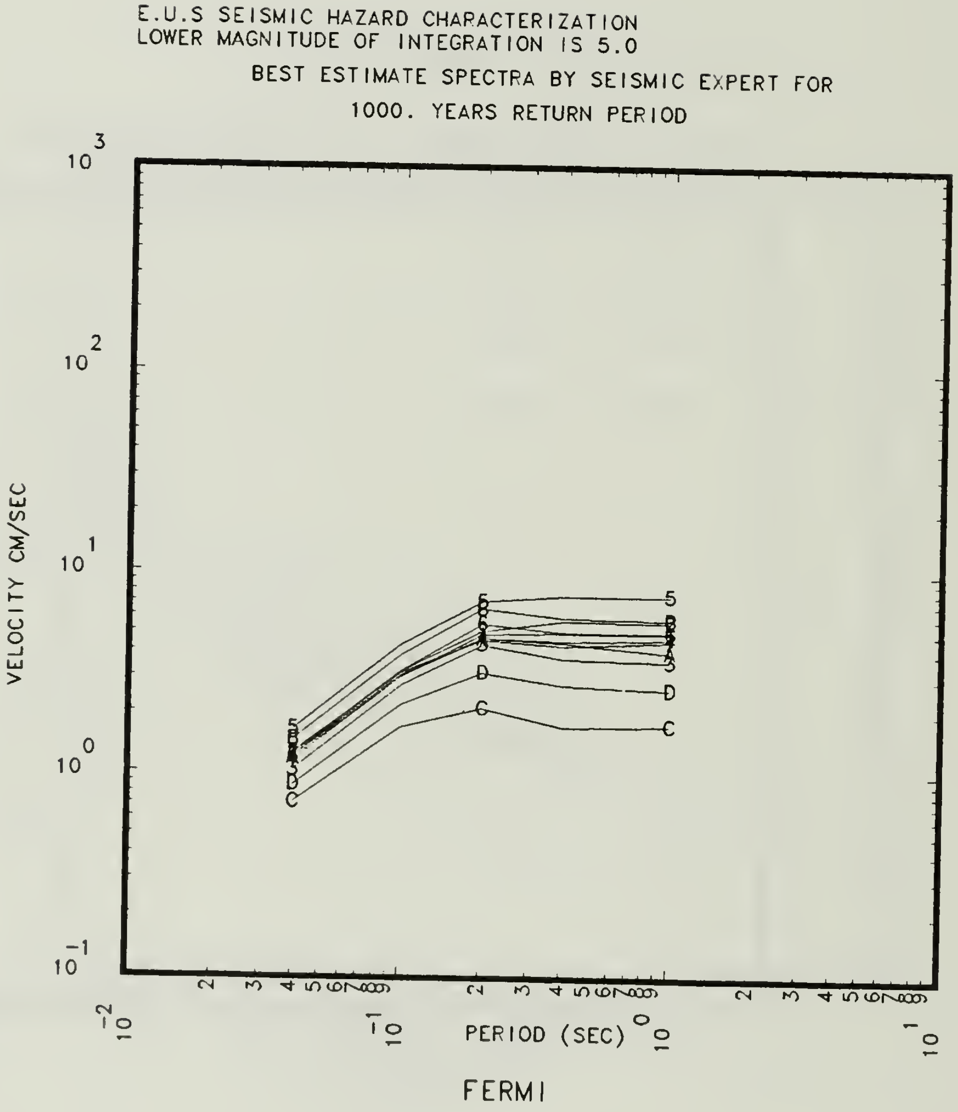


Figure 2.9.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Fermi site. Plot symbols are given in Table 2.0.

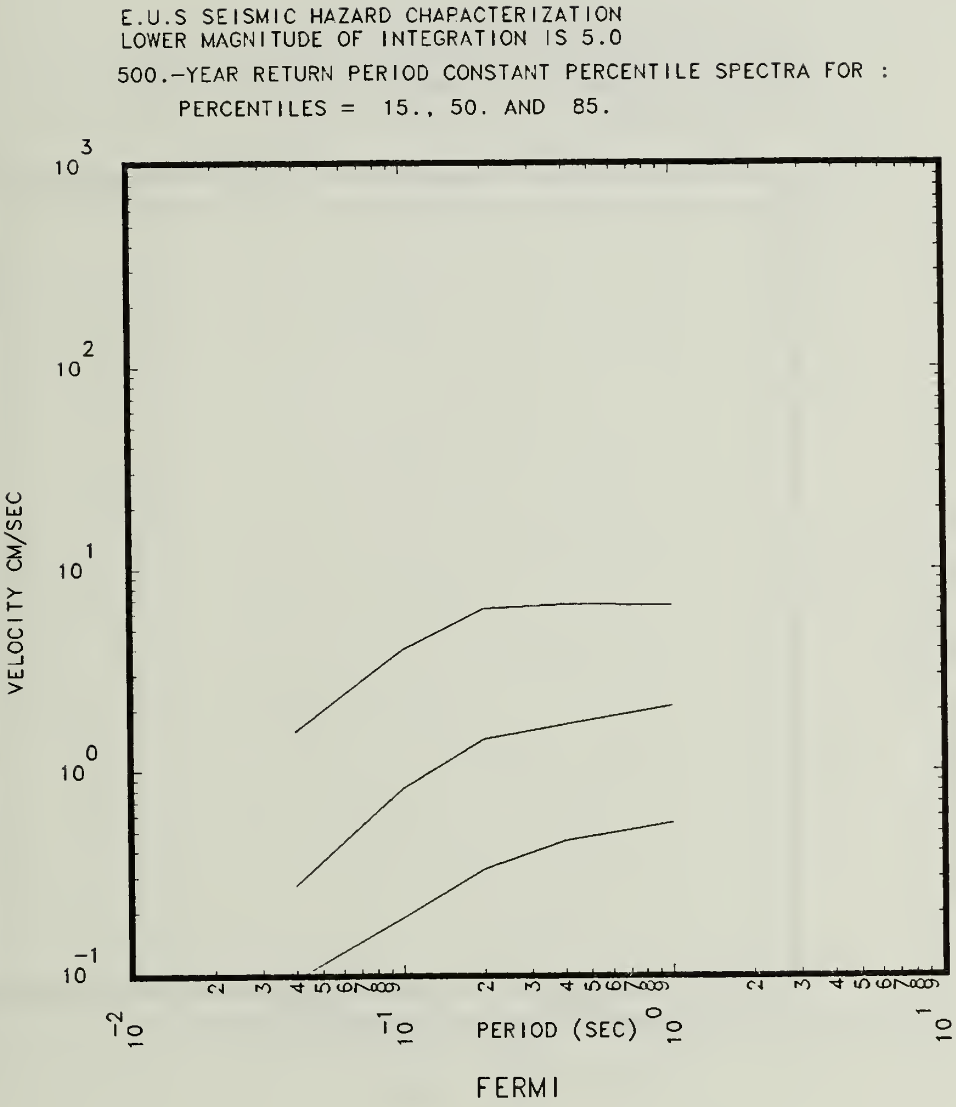


Figure 2.9.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Fermi site.

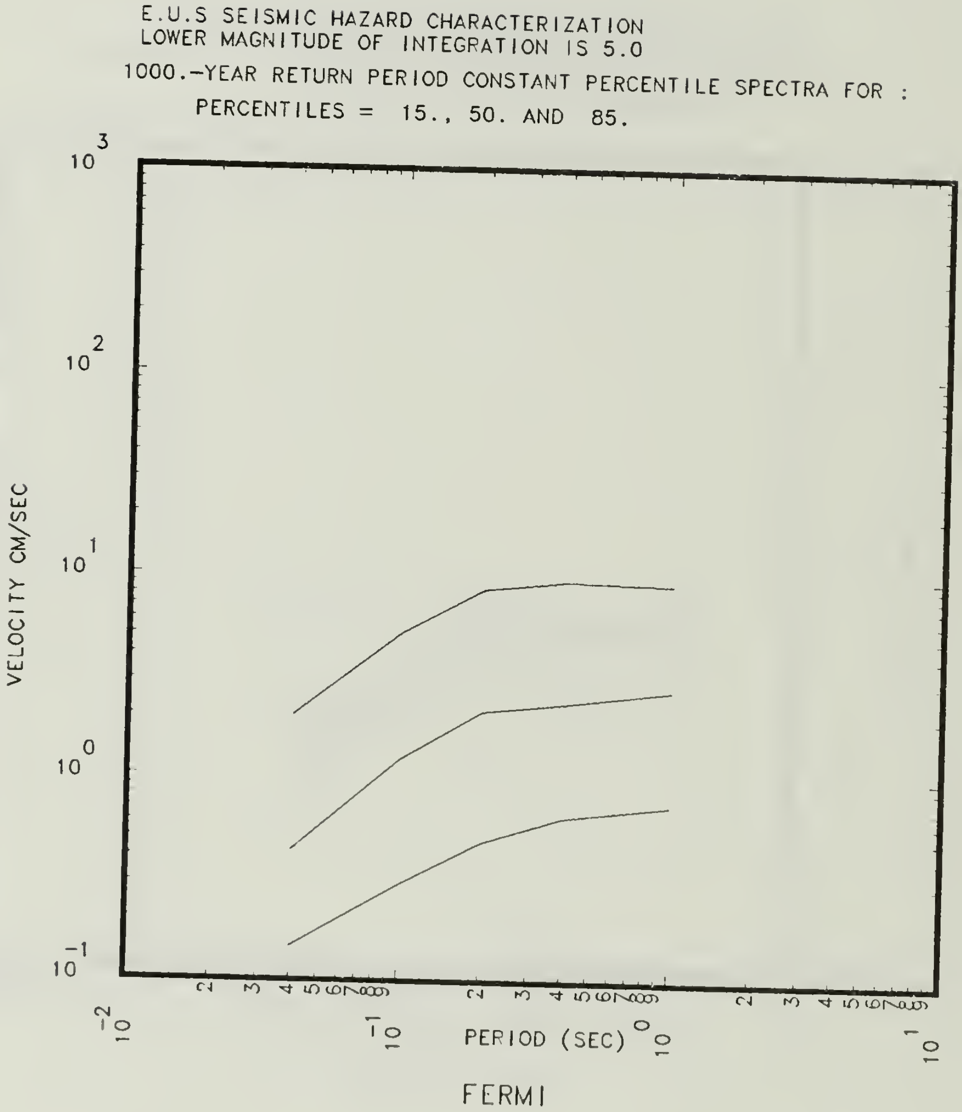


Figure 2.9.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Fermi site.

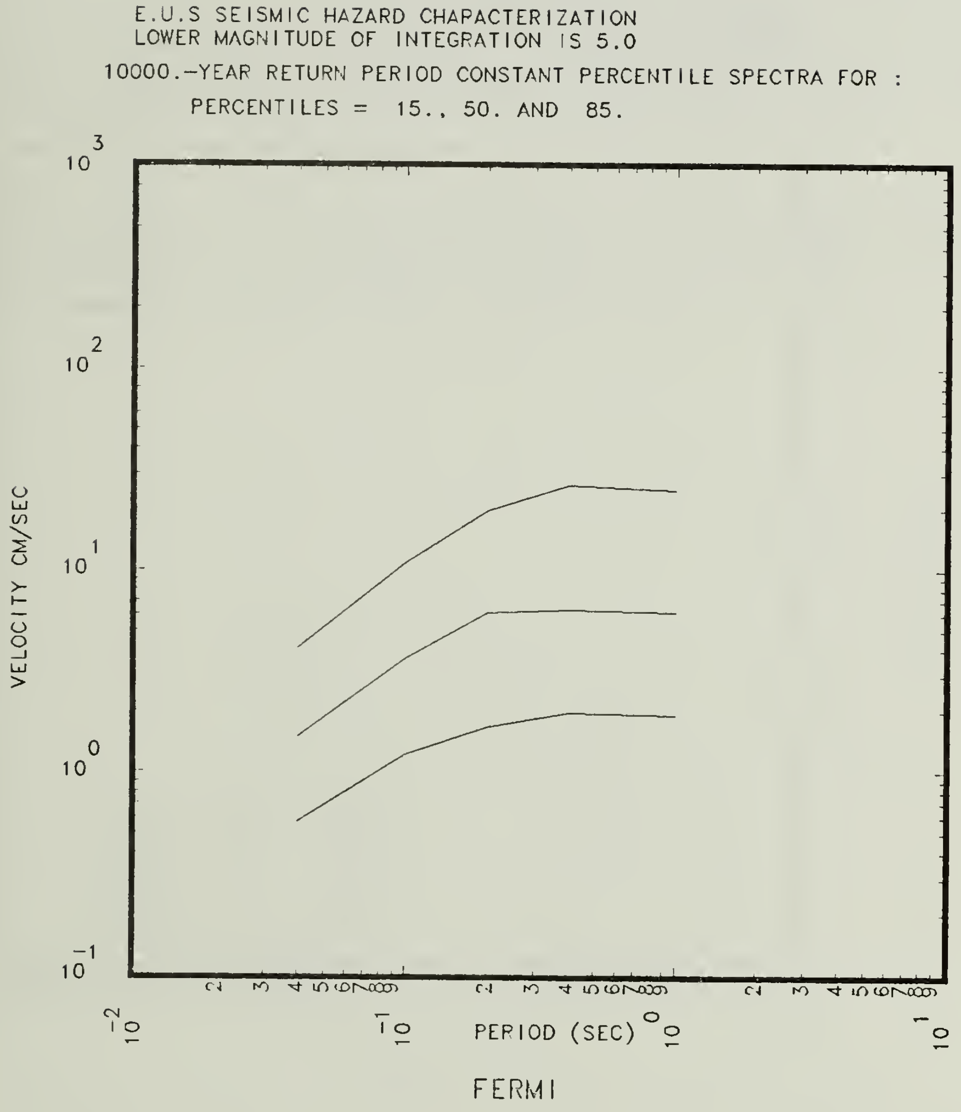


Figure 2.9.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Fermi site.

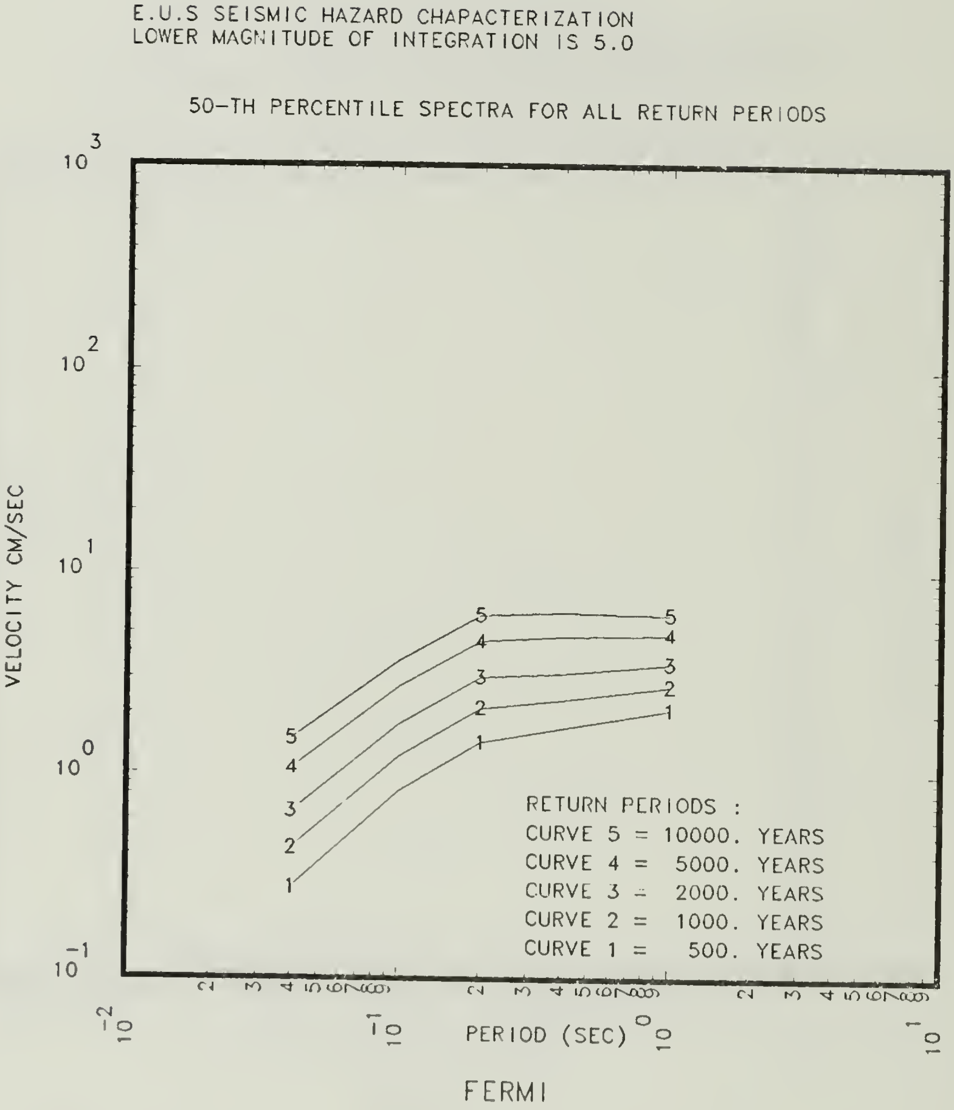


Figure 2.9.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Fermi site.

2.10 KEWAUNEE

The Kewaunee site's soil category is till-like 2 and it is represented by the symbol "A" on Fig. 1.1. Table 2.10.1 and Figs. 2.10.1 through 2.10.10 give the basic results for the Kewaunee site.

The BEHC is approximately equal to the median CPHC and the AMHC is approximately equal to the 85th percentile CPHC.

We see from Table 2.1 that for S-Experts 1, 2, 4, 5, 7 and 12 that the distant New Madrid zone is a significant contributor to the BEHC for PGA. For S-Experts 1, 2, 4, 5, 7 and 12 the spread between the G-Experts' BEHCs per S-Expert is similar to the spread shown in Fig. 2.10.11. We also see from Table 2.10.1 that for S-Experts 3, 6, 10, 11 and 13 that zones nearby the site contribute most to the BEHC for PGA.The spread between the G-Experts' BEHCs for S-Experts 3, 6, 10, 11 and 13 are similar to the spread shown in Fig. 2.10.12.

We see from Fig. 2.10.4 that smaller earthquakes contribute most to the BEHC for PGA. If earthquakes in the magnitude range 3.75 to 5.0 were included in the analysis, the BEHC for PGA would be increased by about a factor of 2 after probability of exceedance between 0.05g to about 0.3g.

TABLE 2.10.1

MOST IMPORTANT ZONES PER S-EXPERT FOR KEWAUNEE

SITE SOIL CATEGORY TILL-2

S-XPT NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 15	ZONE ID:	ZONE 9	ZONE 15	ZONE 11	ZONE 10	ZONE 15	ZONE 9	ZONE 11	ZONE 19
		% CONT.:	34.	32.	16.	11.	76.	23.	1.	1.
2	COMP. ZO	ZONE ID:	ZONE 18	COMP. ZON	ZONE 20	ZONE 21	COMP. ZON	ZONE 18	ZONE 13	ZONE 15
		% CONT.:	50.	46.	3.	1.	81.	19.	0.	0.
3	COMP. ZO	ZONE ID:	COMP. ZON	ZONE 15	ZONE 13	ZONE 12	COMP. ZON	ZONE 13	ZONE 15	ZONE 2
		% CONT.:	82.	9.	3.	3.	100.	0.	0.	0.
4	ZONE 13	ZONE ID:	ZONE 4	ZONE 6	ZONE 13	ZONE 5	ZONE 13	ZONE 4	ZONE 6	COMP. ZON
		% CONT.:	48.	30.	13.	4.	59.	34.	6.	1.
5	COMP. ZO	ZONE ID:	ZONE 15	COMP. ZON	ZONE 13	ZONE 12	COMP. ZON	ZONE 15	ZONE 13	ZONE 4
		% CONT.:	44.	23.	18.	9.	58.	42.	0.	0.
6	COMP. ZO	ZONE ID:	COMP. ZON	ZONE 17	ZONE 22	ZONE 7	COMP. ZON	ZONE 22	ZONE 17	ZONE 18
		% CONT.:	56.	17.	16.	4.	96.	3.	1.	0.
7	ZONE 3	ZONE ID:	ZONE 6	ZONE 3	ZONE 5	ZONE 4	ZONE 3	ZONE 6	ZONE 2 =	ZONE 4
		% CONT.:	66.	30.	1.	1.	73.	26.	1.	0.
10	ZONE 27	ZONE ID:	ZONE 19 =	ZONE 27	ZONE 26A	ZONE 12A	ZONE 27	ZONE 19 =	ZONE 26A	ZONE 5
		% CONT.:	75.	20.	3.	1.	53.	47.	0.	0.
11	CZ = ZON	ZONE ID:	CZ = ZONE	ZONE 10	ZONE 11	ZONE 9	CZ = ZONE	ZONE 2	ZONE 5	ZONE 6
		% CONT.:	96.	3.	1.	0.	100.	0.	0.	0.
12	ZONE 4 =	ZONE ID:	ZONE 31A	ZONE 31	ZONE 15	ZONE 13	ZONE 15	ZONE 5	ZONE 6	ZONE 7
		% CONT.:	47.	22.	22.	5.	100.	0.	0.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 5	ZONE 6	ZONE 11	CZ 15	ZONE 5	ZONE 3	ZONE 4
		% CONT.:	97.	3.	0.	0.	100.	0.	0.	0.

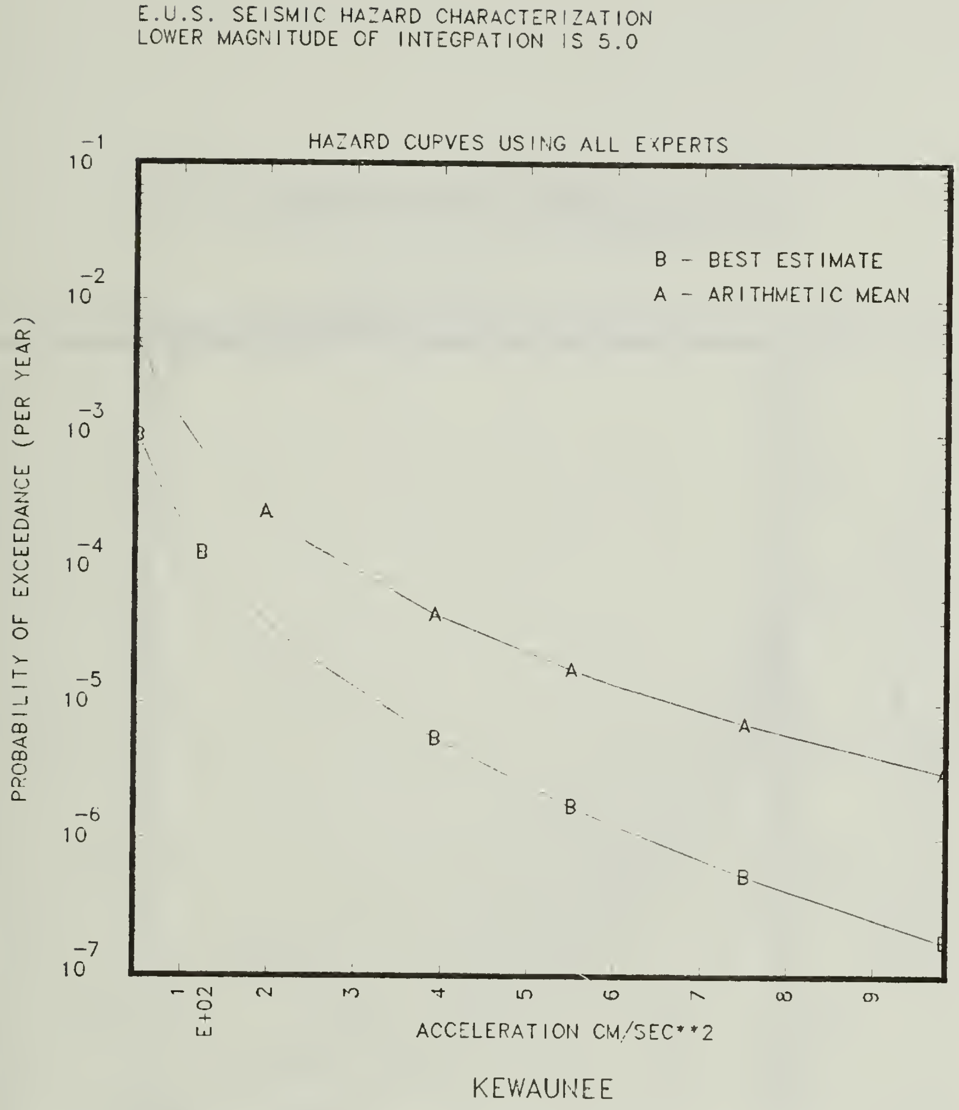


Figure 2.10.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Kewaunee site.

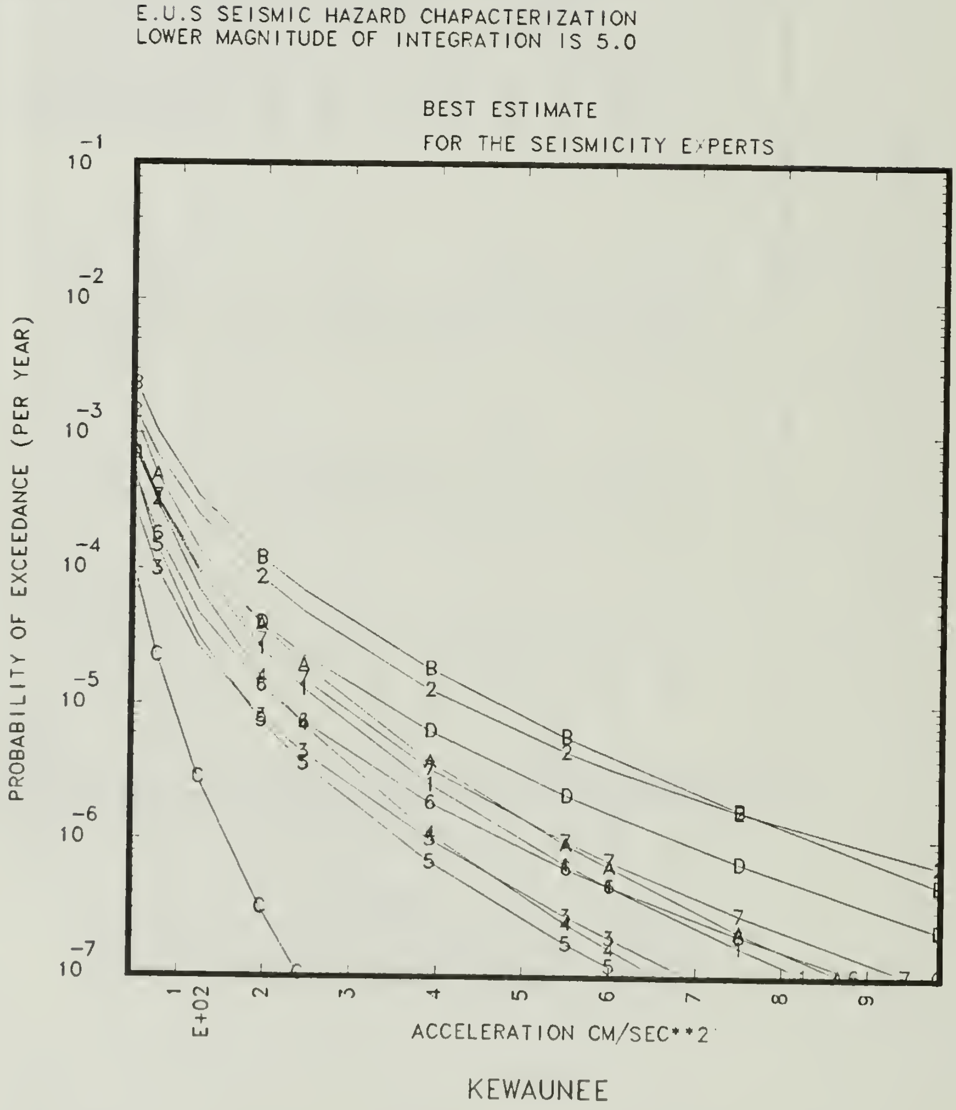


Figure 2.10.2 BEHCs per S-Expert combined over all G-Experts for the Kewaunee site. Plot symbols given in Table 2.0.

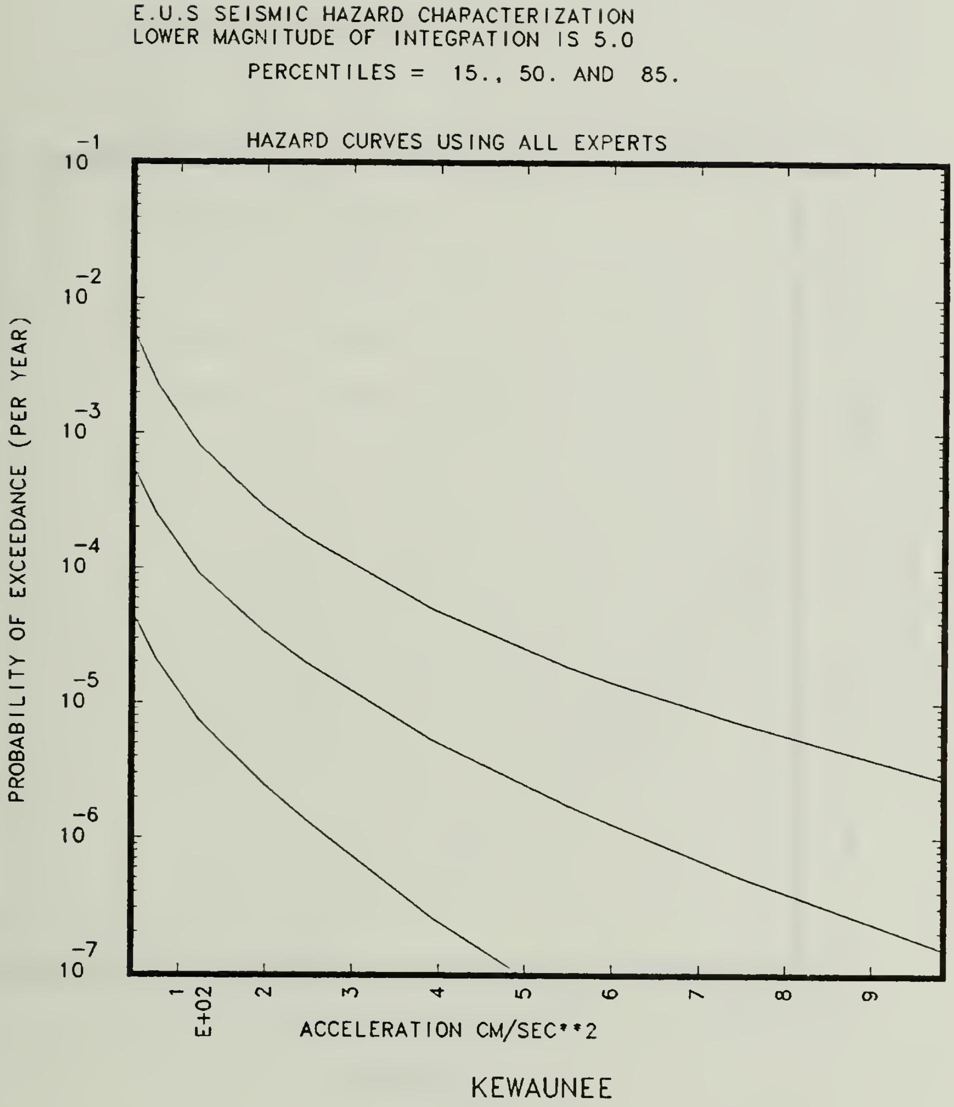
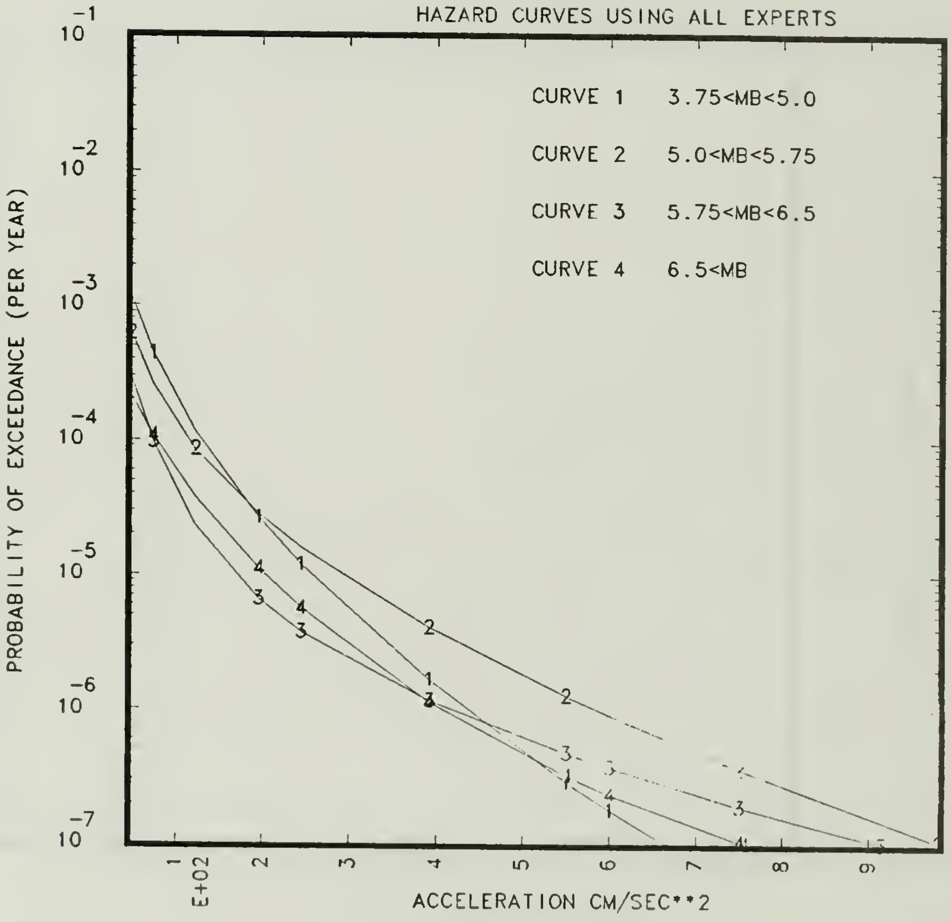
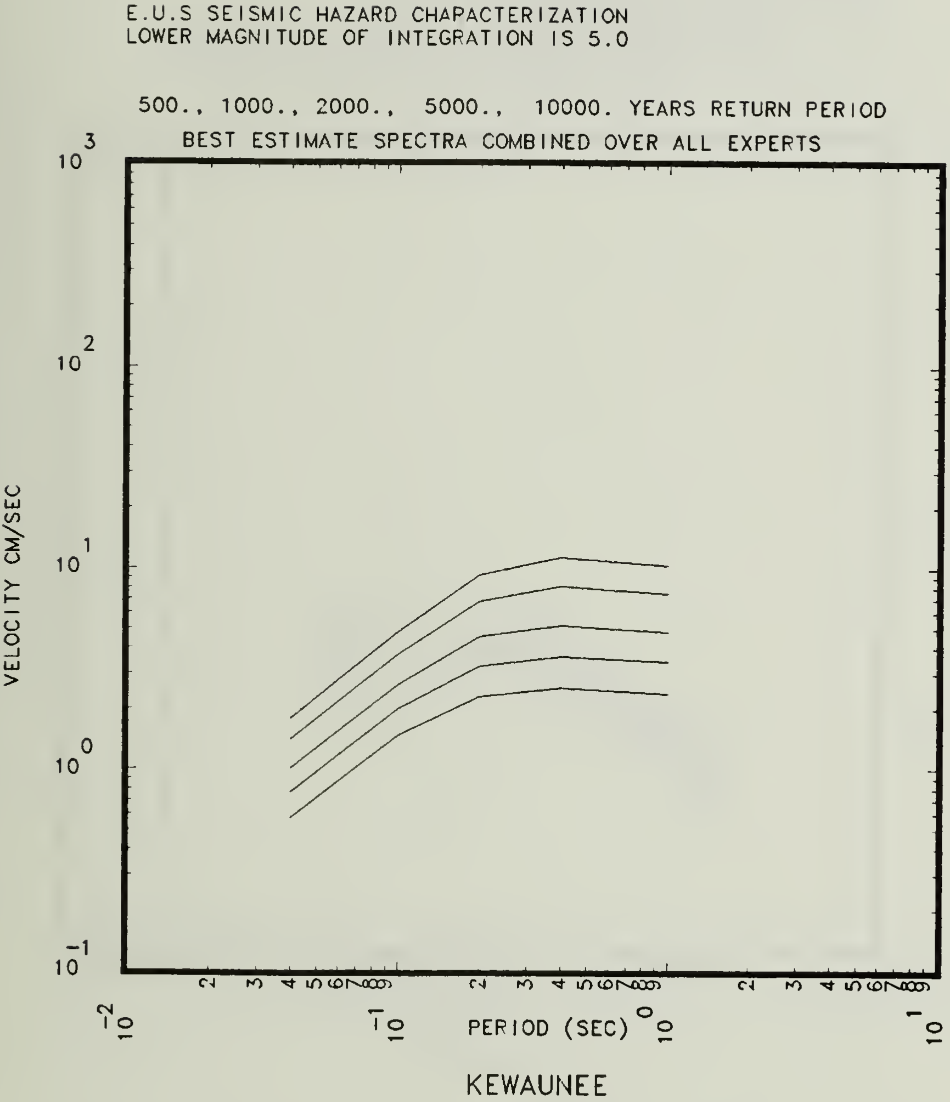


Figure 2.10.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Kewaunee site.



KEWAUNEE

Figure 2.10.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Kewaunee site.



re 2.10.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Kewaunee site.

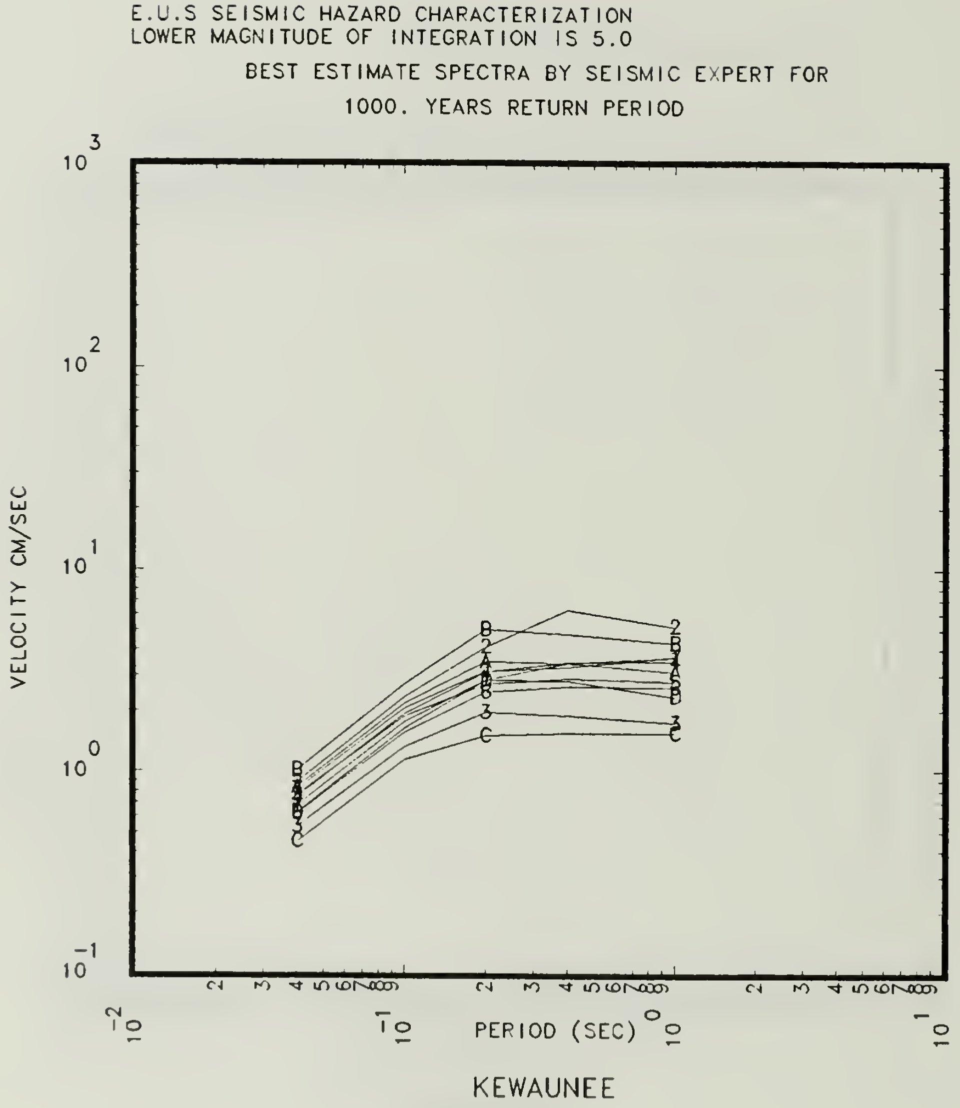
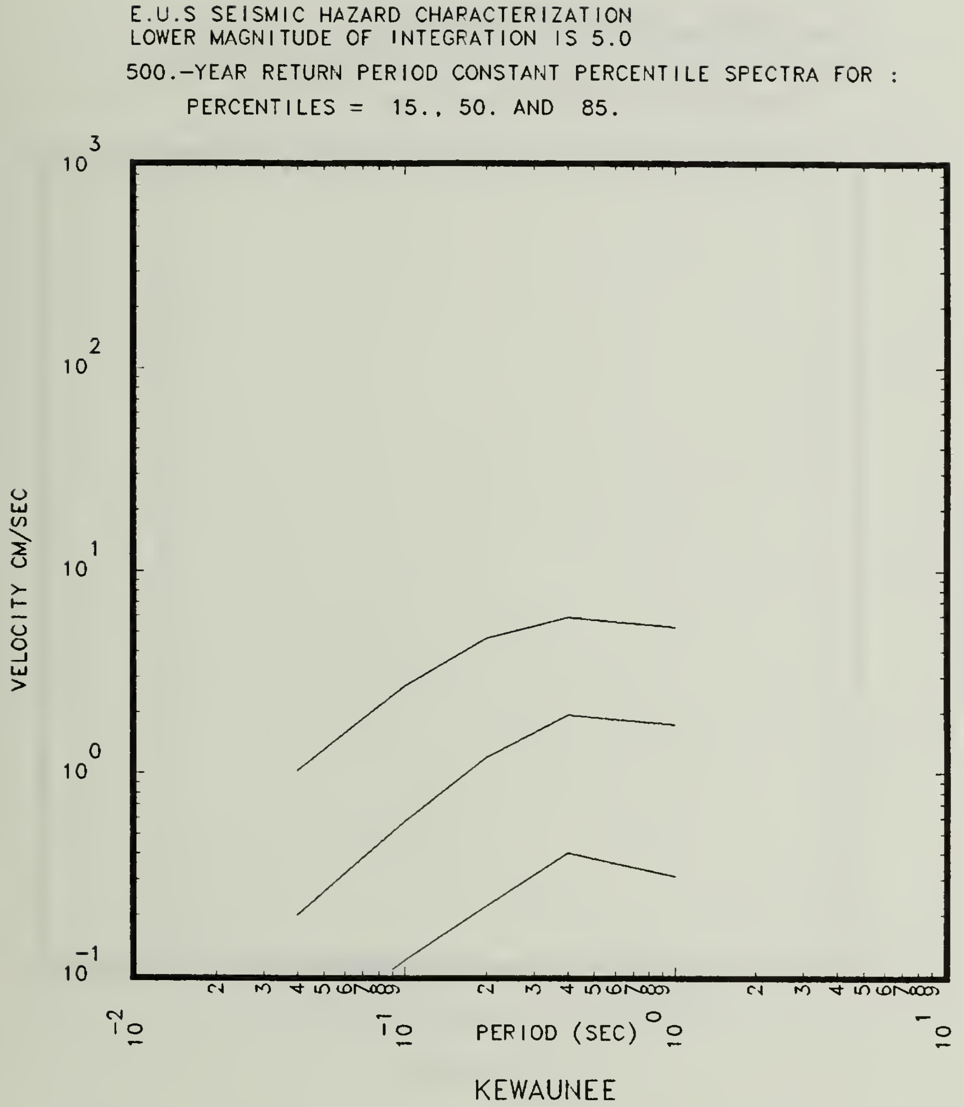


Figure 2.10.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Kewaunee site. Plot symbols are given in Table 2.0.



ure 2.10.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Kewaunee site.

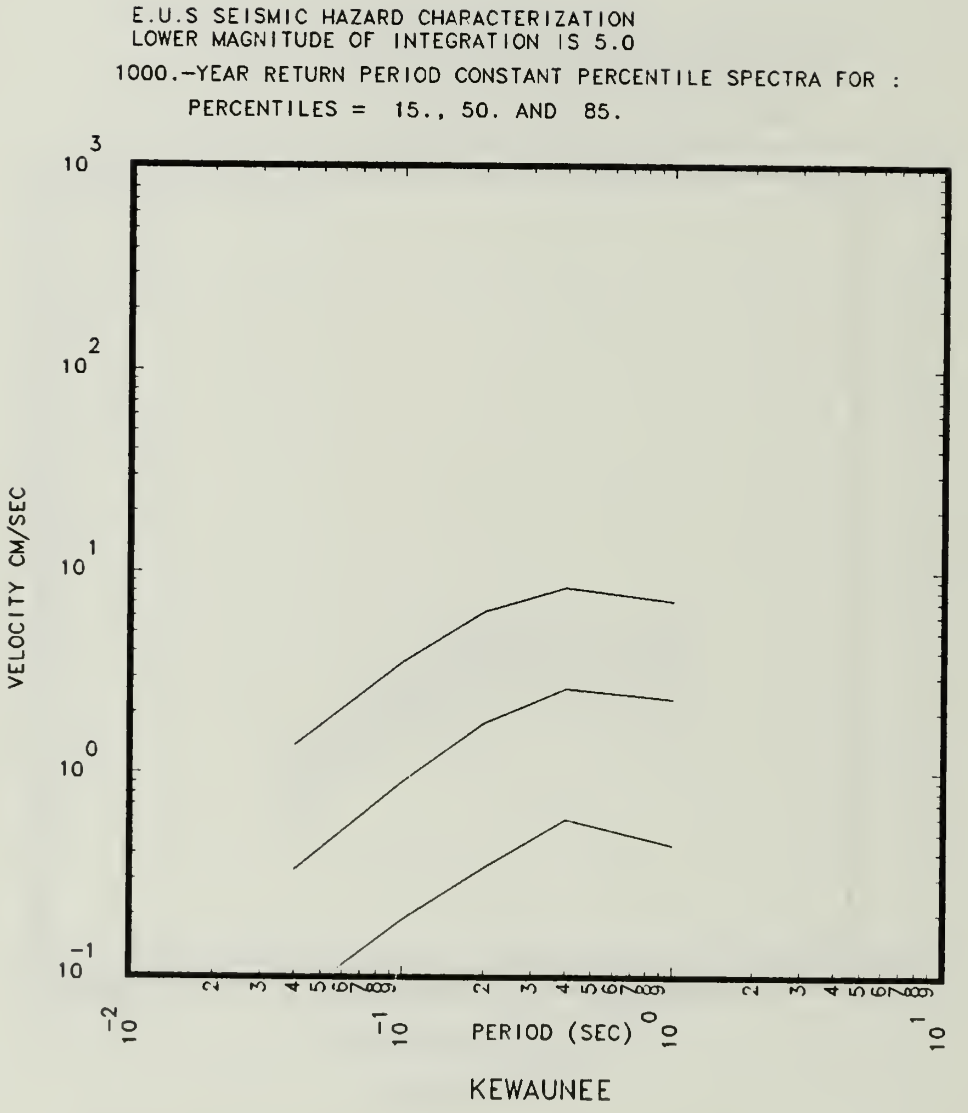


Figure 2.10.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Kewaunee site.

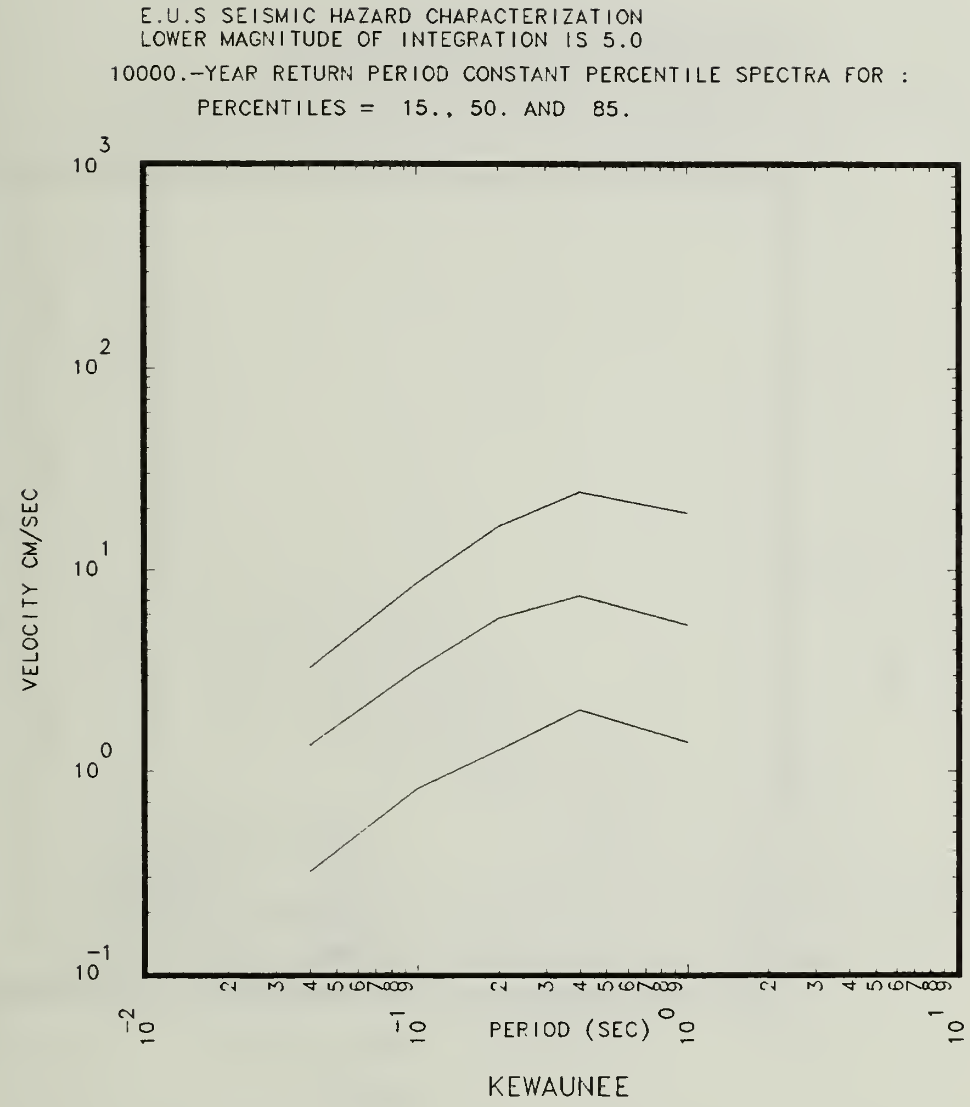
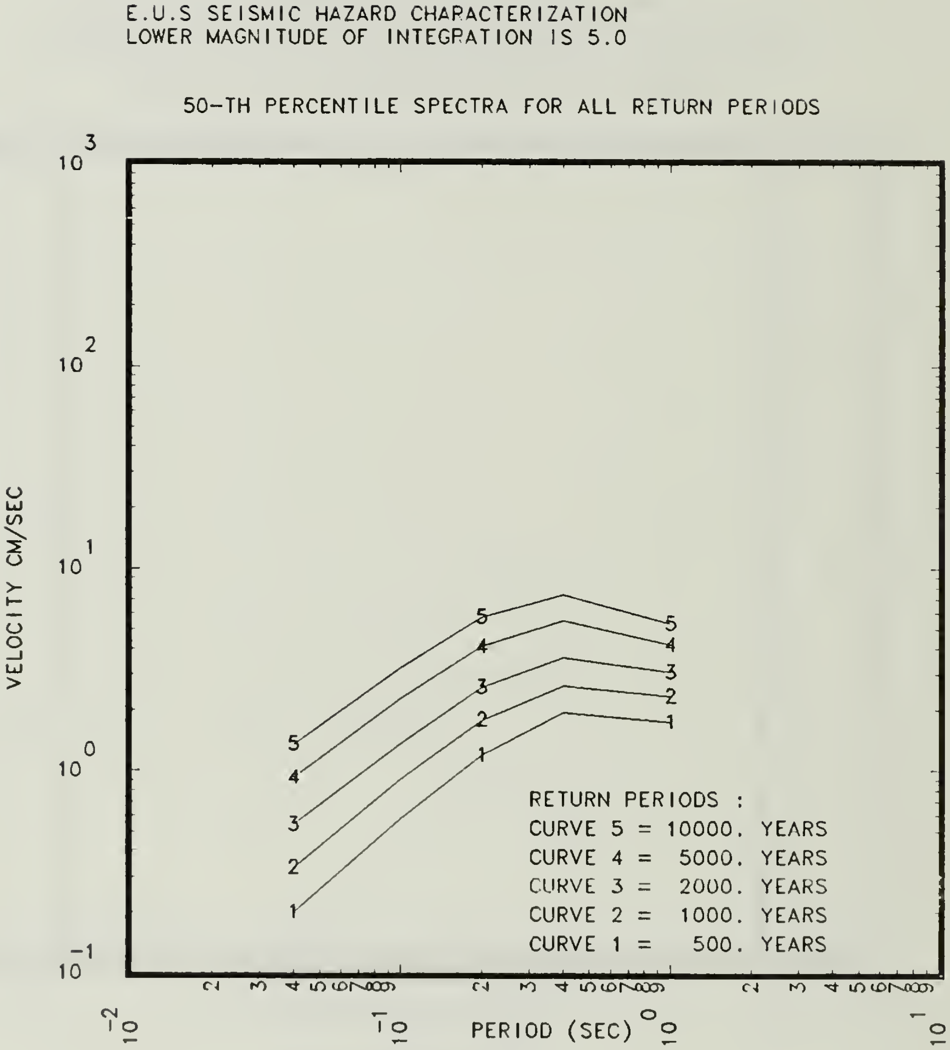


Figure 2.10.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Kewaunee site.



KEWAUNEE

Figure 2.10.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Kewaunee site.

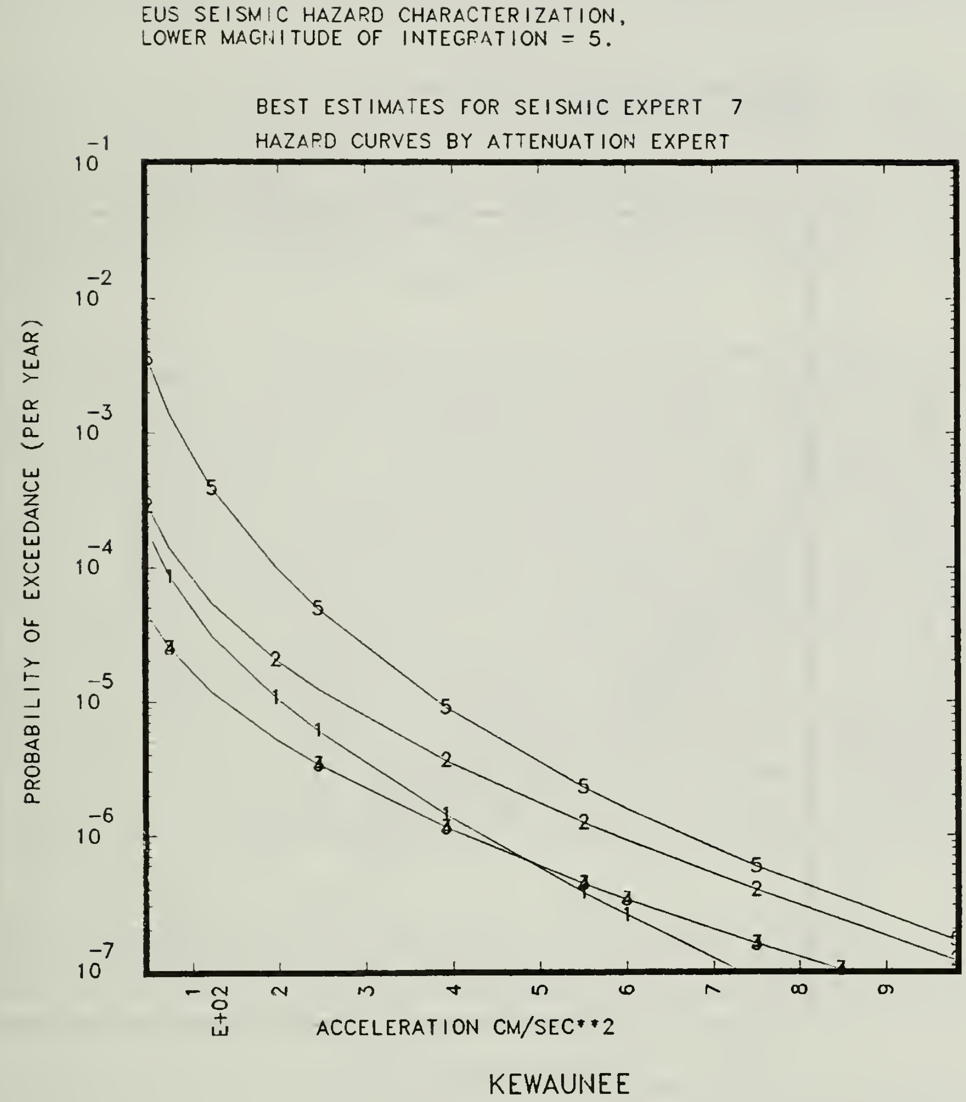


Figure 2.10.11 The BEHCs per G-Expert for S-Expert 7's input for the Kewaunee site. The spread between the G-Experts' BEHCs is also typical for S-Experts 1,2,4,5 and 12 for the Kewaunee site.

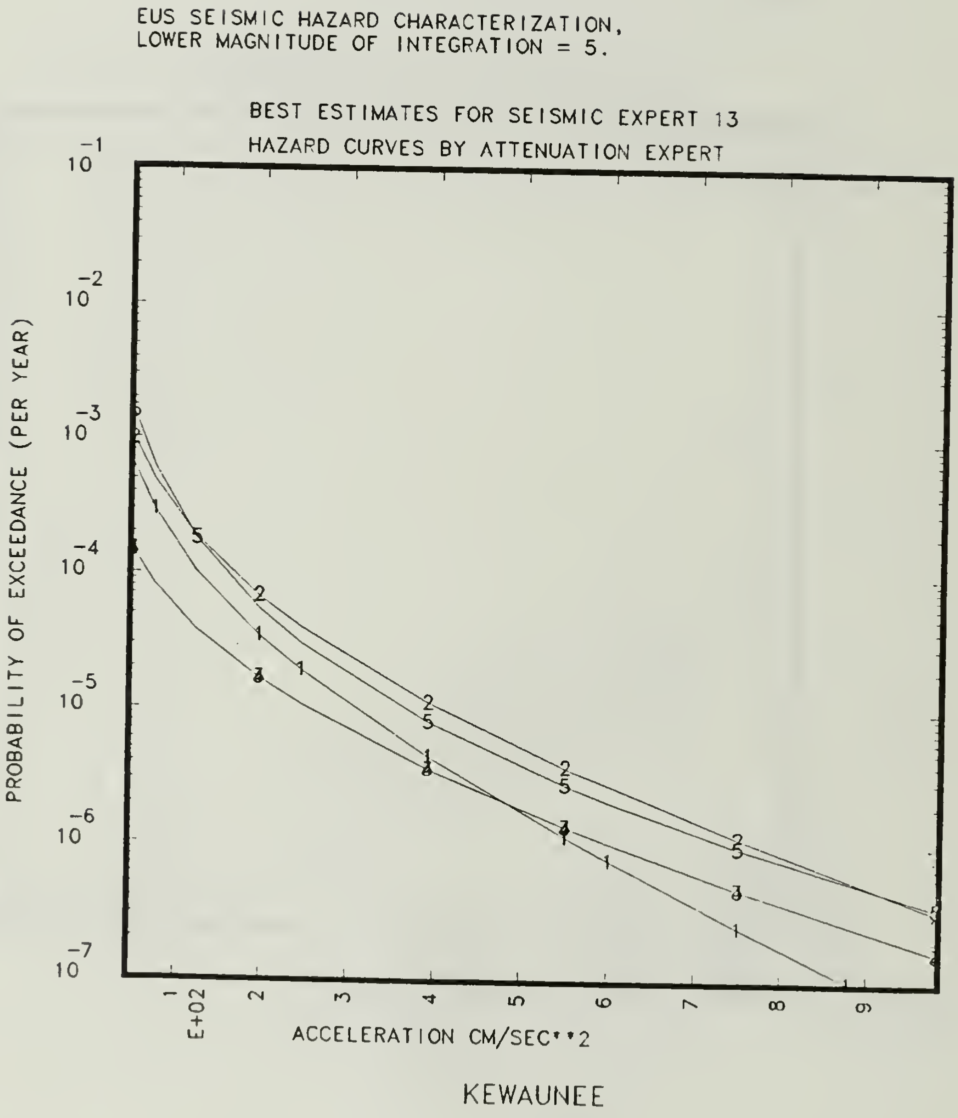


Figure 2.10.12 The BEHCs per G-Expert for S-Expert 13's input for the Kewaunee site. The spread between the G-Experts' BEHCs is also typical for S-Experts 3,6,10 and 11 for the Kewaunee site.

2.11 LASALLE

The LaSalle site's soil category is till-like 2 and it is represented by the symbol "B" in Fig. 1.1. Table 2.11.1 and Figs. 2.11.1 through 2.11.10 give the basic results for the LaSalle site.

It can be seen from Fig. 1.1 that the LaSalle site is very near the Braidwood and Dresden sites. However, the results are somewhat different for the LaSalle site compared to the results for the Braidwood and Dresden sites because both Braidwood and Dresden are rock sites whereas the LaSalle site is a shallow soil site.

We see from Table 2.11.1 that the New Madrid zone contributes significantly to the BEHC for PGA for S-Experts 1, 2, 4, 5, 7 and 12. However, if Table 2.11.1 is compared to Table 2.3.1, we see that generally the percent contributed from the distant New Madrid zones is lower at the LaSalle site than at the Braidwood site. This is partly because the correction for soil conditions is lower for G-Expert 5's BE GM model at LaSalle than at Braidwood. See the discussion in Section 2.3 about G-Expert 5's GM model.

S-Experts 1, 2, 4, 5, 6 and 12, for which the distant New Madrid zones contribute significantly to the BEHC for PGA and S-Expert 6 where the somewhat distant zone 17 contributes significantly to the hazard, have a wider spread between the G-Experts' BEHCs per S-Expert than the spread between the G-Experts' BEHCs for S-Expert 3, 10 and 13 where the nearby zones contribute 90 percent or more to the BEHC for PGA. The spread between the G-Experts' BEHCs for S-Experts 3, 10 and 13 for the LaSalle site is similar to the spread shown in Fig. 2.1.11. For S-Experts 1, 4, 6 and 11 where the distant New Madrid zone or other somewhat distant zones with large earthquakes, e.g., zone 17 for S-Expert 6 and zone 10 for S-Expert 11, only contribute about 10 to 25 percent of the hazard the spread between the G-Experts' BEHCs is similar to that shown in Fig. 2.5.11. The spread between G-Expert 5's BEHC and the other G-Experts BEHCs for S-Experts 2, 5, 7 and 12 is related to the percent contributed from the New Madrid zone. Thus for S-Experts 2 and 7 the spread is about the same as shown in Fig. 2.5.12 whereas for S-Experts 5 and 12 the spread between G-Expert 5's BEHC and the other G-Experts is large and similar to the spread shown in Fig. 2.5.13.

We see from Fig. 2.11.4 that earthquakes of all ranges contribute significantly to the BEHC for PGA. We also see that if earthquakes in the magnitude range 3.75 to 5.0 were included that the hazard would only be increased at the low g value end.

The spectra shown on Fig. 2.11.10 for LaSalle are markedly different from those of 2.3.10 for the Braidwood, even though those two sites are close to each other. The main difference between these two sites is in their soil conditions, with Braidwood being a rock site and LaSalle being a shallow soil site of category T-2. Fig. 3.13 in Vol. I shows that the amplification curve has a high point at 0.4 second period, hence the difference between LaSalle and Braidwood at 0.4 second period.

TABLE 2.11.1

MOST IMPORTANT ZONES PER S-EXPERT FOR LASALLE

SITE SOIL CATEGORY TILL-2

S-XPT NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 19	ZONE ID:	ZONE 19	ZONE 11	ZONE 9	ZONE 10	ZONE 19	ZONE 9	ZONE 11	ZONE 10
		% CONT.:	43.	26.	20.	9.	80.	10.	8.	1.
2	COMP. ZO	ZONE ID:	ZONE 18	ZONE 21	ZONE 20	COMP. ZON	ZONE 18	ZONE 21	COMP. ZON	ZONE 20
		% CONT.:	58.	24.	12.	6.	71.	17.	12.	1.
3	ZONE 15	ZONE ID:	ZONE 15	ZONE 16	ZONE 12	ZONE 13	ZONE 15	ZONE 16	ZONE 13	ZONE 12
		% CONT.:	53.	21.	13.	9.	90.	6.	2.	2.
4	COMP. ZO	ZONE ID:	ZONE 6	ZONE 4	ZONE 5	ZONE 3	ZONE 6	ZONE 4	ZONE 5	COMP. ZON
		% CONT.:	53.	37.	8.	1.	77.	21.	1.	0.
5	COMP. ZO	ZONE ID:	ZONE 15	ZONE 14	ZONE 12	COMP. ZON	ZONE 15	COMP. ZON	ZONE 14	ZONE 1
		% CONT.:	76.	9.	9.	5.	94.	6.	0.	0.
6	ZONE 22	ZONE ID:	ZONE 17	ZONE 22	ZONE 18	ZONE 9	ZONE 22	ZONE 17	ZONE 18	COMP. ZON
		% CONT.:	49.	42.	4.	3.	72.	26.	1.	1.
7	ZONE 34	ZONE ID:	ZONE 6	ZONE 34	ZONE 5	ZONE 2 =	ZONE 6	ZONE 34	ZONE 2 =	ZONE 5
		% CONT.:	67.	25.	6.	2.	65.	34.	1.	0.
10	ZONE 26A	ZONE ID:	ZONE 26A	ZONE 19 =	ZONE 12A	ZONE 13	ZONE 26A	ZONE 19 =	ZONE 12A	ZONE 4B
		% CONT.:	65.	28.	5.	2.	88.	12.	0.	0.
11	CZ = ZON	ZONE ID:	ZONE 10	CZ = ZONE	ZONE 11	ZONE 9	CZ = ZONE	ZONE 10	ZONE 11	ZONE 5
		% CONT.:	56.	40.	4.	0.	75.	25.	0.	0.
12	ZONE 4 =	ZONE ID:	ZONE 15	ZONE 13	ZONE 14	ZONE 31A	ZONE 15	ZONE 14	ZONE 13	ZONE 5
		% CONT.:	47.	36.	17.	0.	98.	2.	0.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 5	ZONE 6	ZONE 4	CZ 15	ZONE 5	ZONE 6	ZONE 1
		% CONT.:	72.	21.	7.	0.	96.	4.	0.	0.

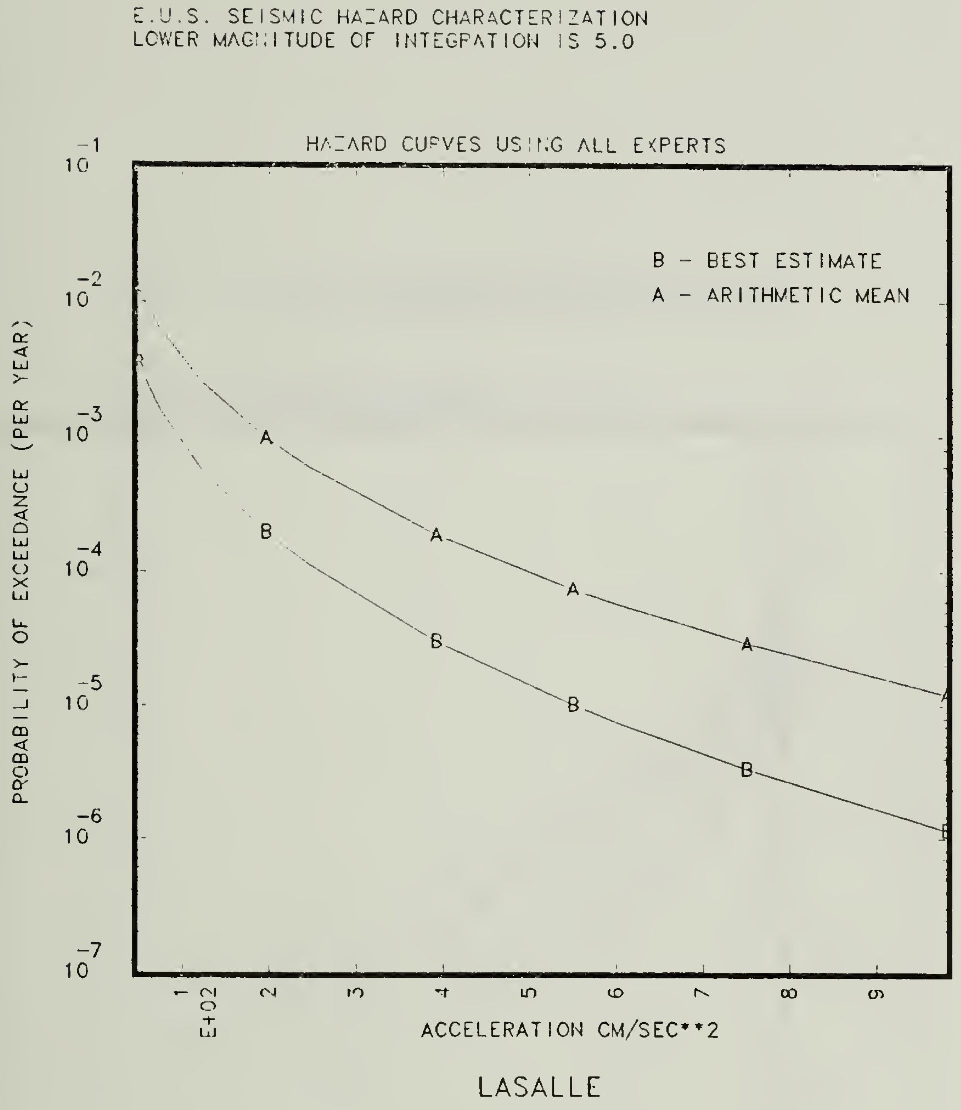


Figure 2.11.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the LaSalle site.

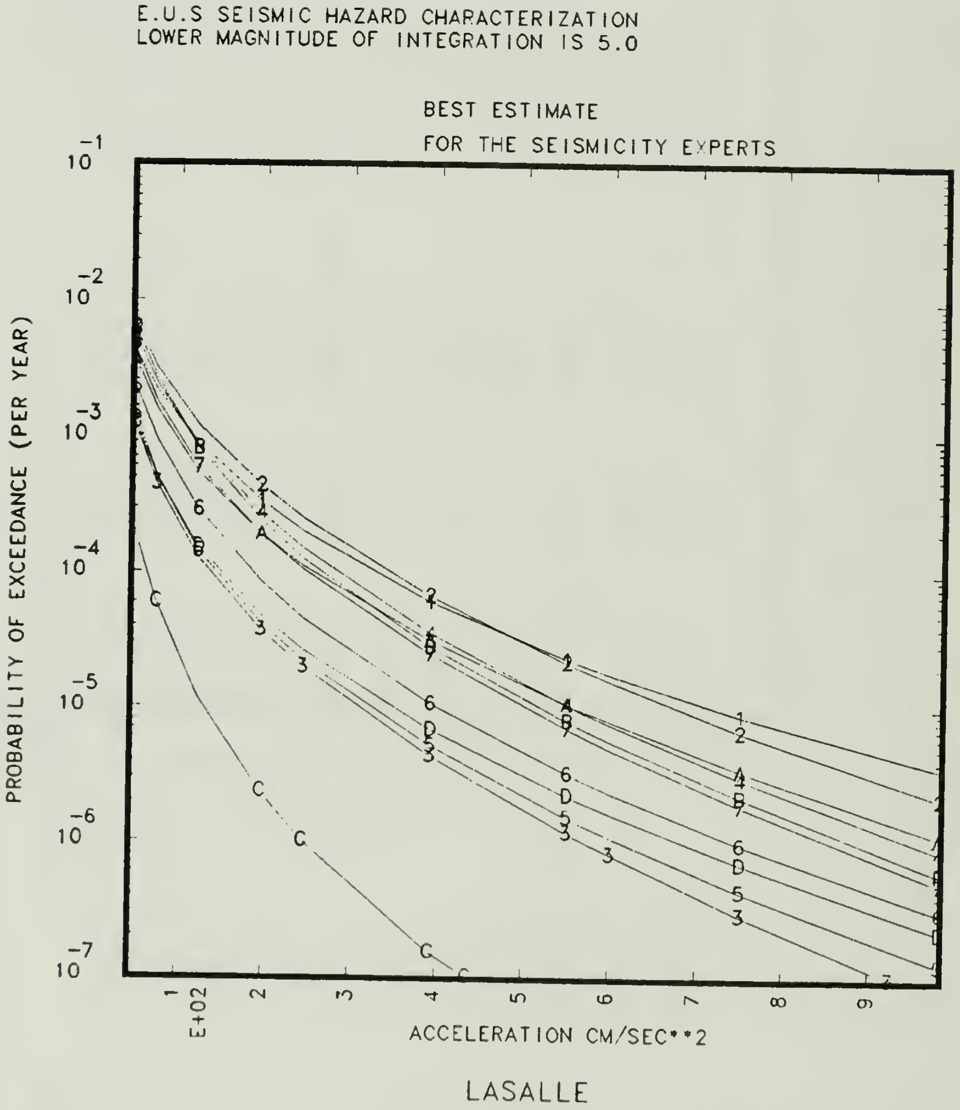
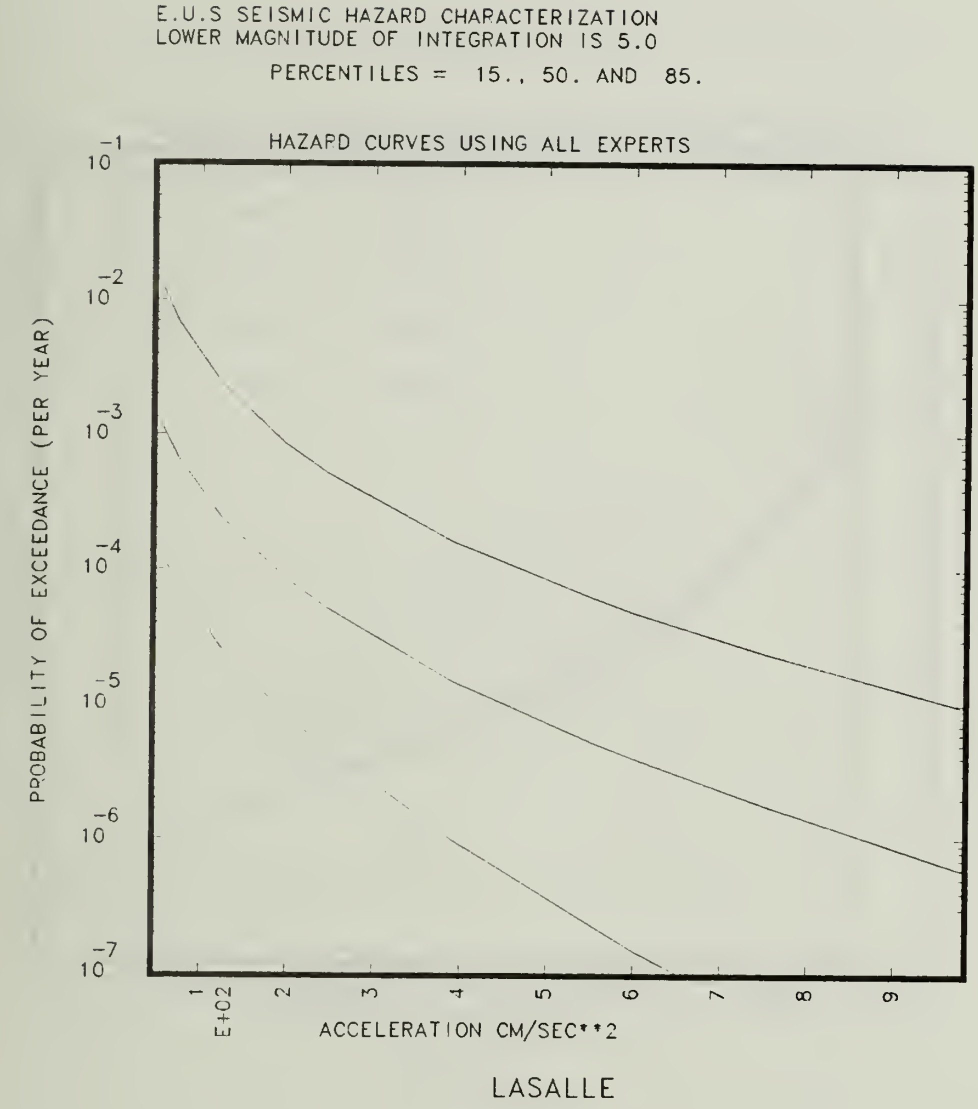
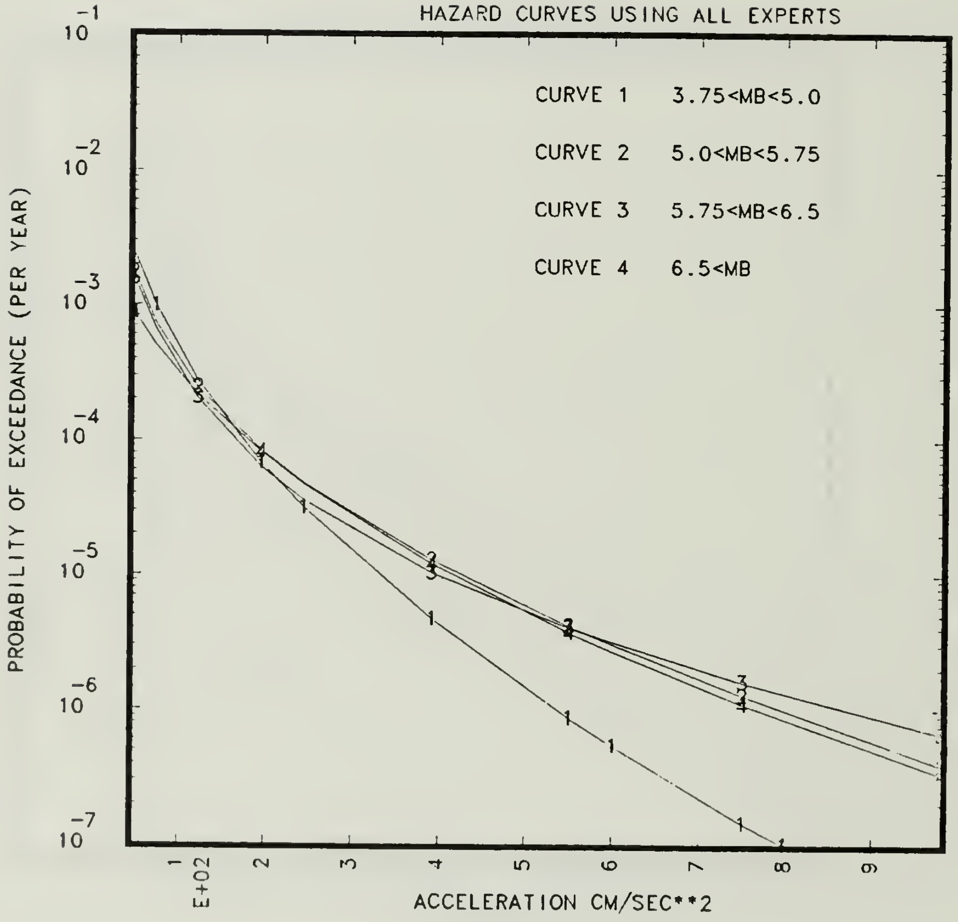


Figure 2.11.2 BEHCs per S-Expert combined over all G-Experts for the LaSalle site. Plot symbols given in Table 2.0.



igure 2.11.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the LaSalle site.



LASALLE

Figure 2.11.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the LaSalle site.

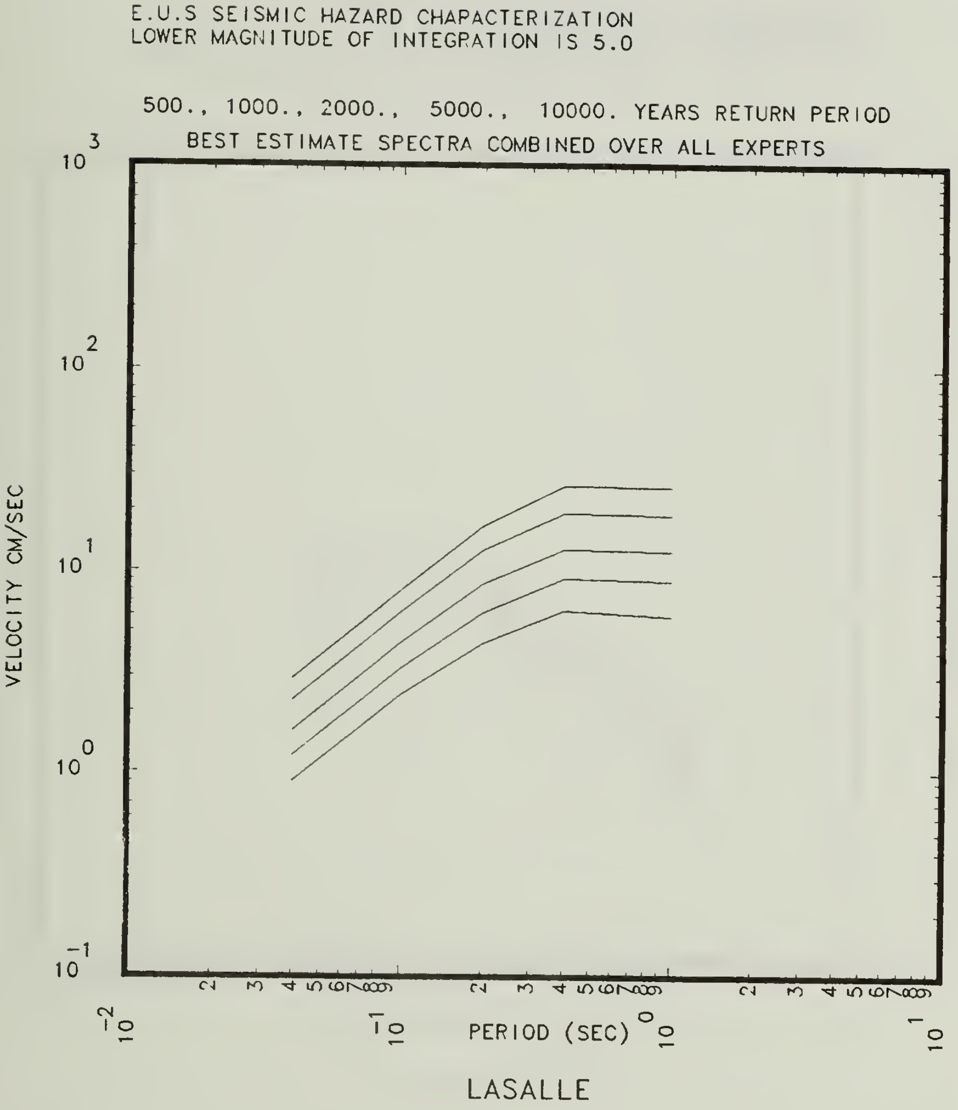


Figure 2.11.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the LaSalle site.

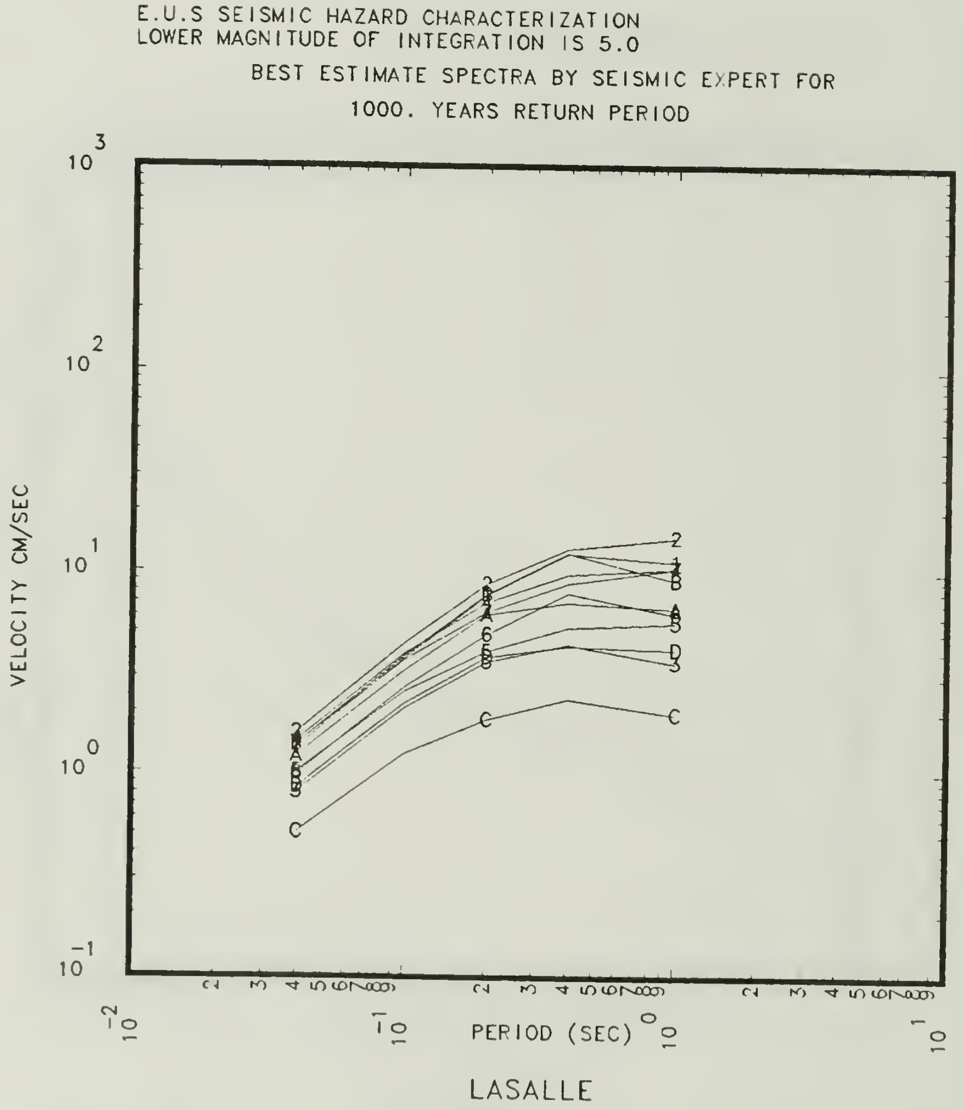


Figure 2.11.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the LaSalle site. Plot symbols are given in Table 2.0.

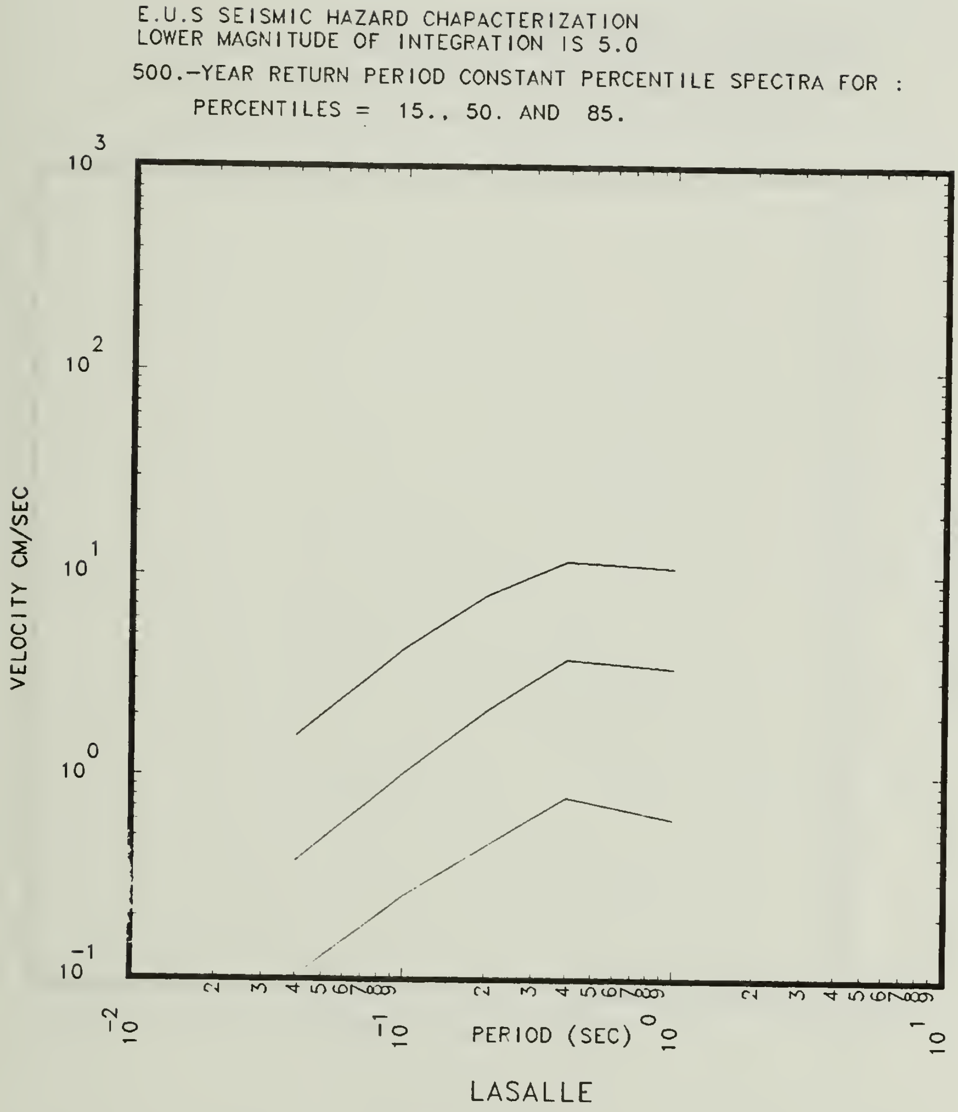


Figure 2.11.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the LaSalle site.

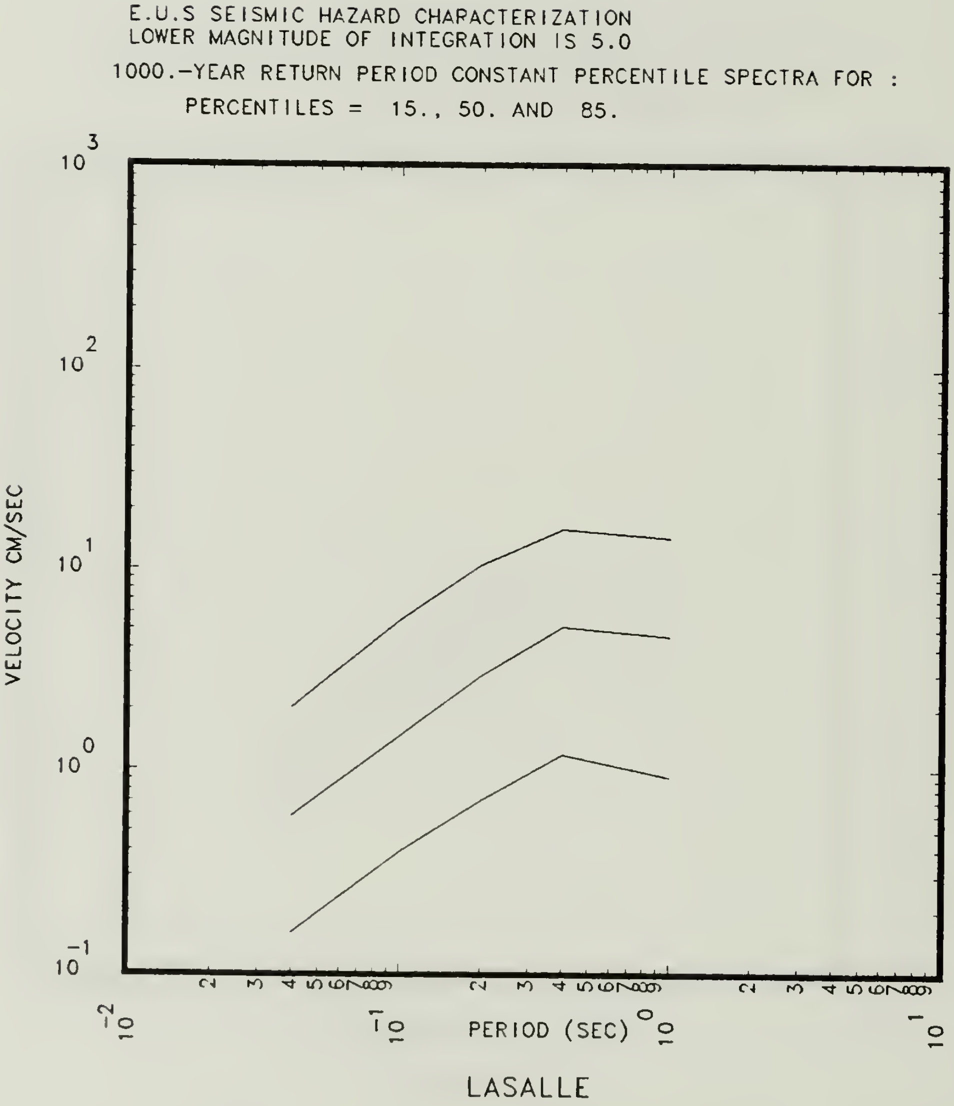


Figure 2.11.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the LaSalle site.

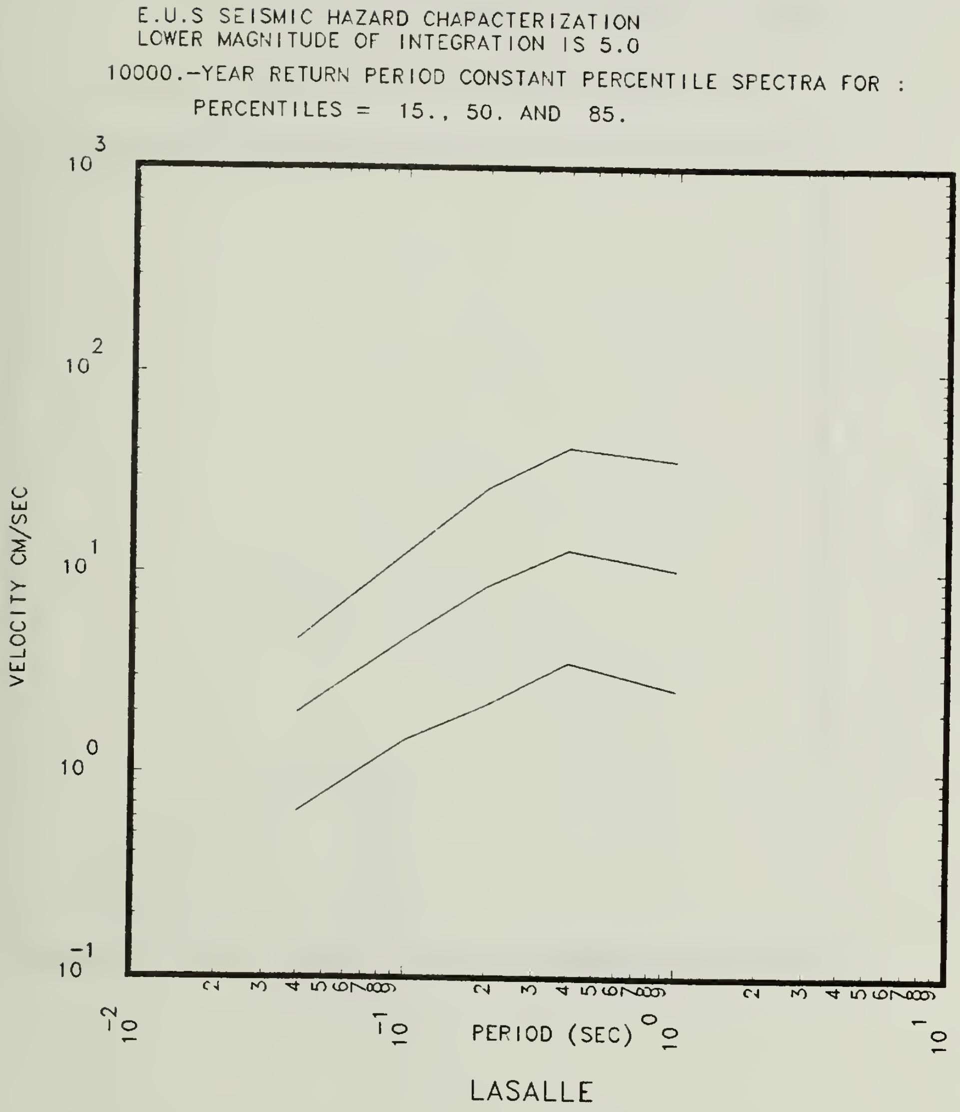


Figure 2.11.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the LaSalle site.

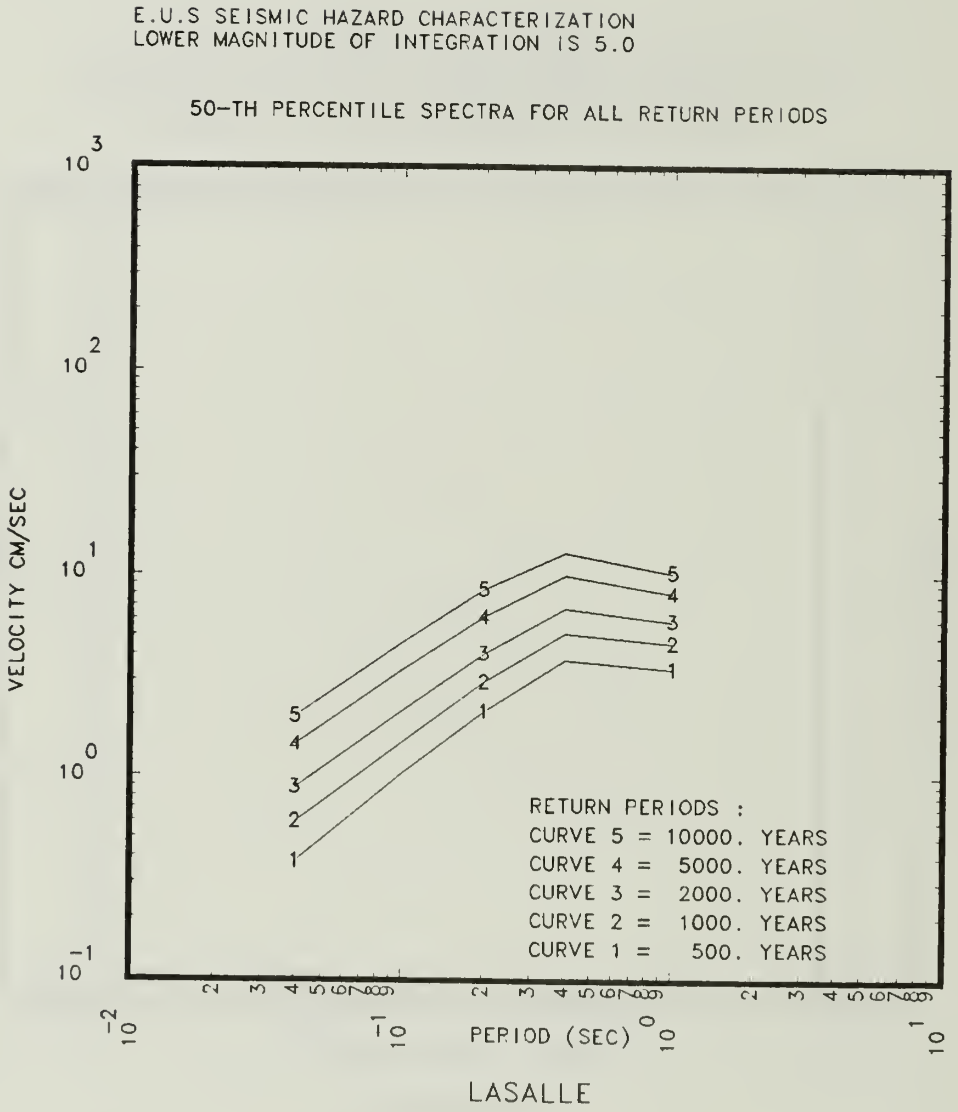


Figure 2.11.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the LaSalle site.

2.12 PALISADES

The Palisades site's soil category is sand-like 2 and it is represented by the symbol "C" in Fig. 1.1. Table 2.12.1 and Figs. 2.12.1 through 2.12.10 give the basic results for the Palisades site.

We see from Fig. 1.1 that the Palisades site is near the Cook site. The Cook site's soil category is the same as the Palisades site's soil category. There are only minor differences in the results between the two sites thus the discussions given in Section 2.6 for the Cook site holds for the Palisades site and is not repeated here.

TABLE 2.12.1

```
                     MOST IMPORTANT ZONES PER S-EXPERT
                           FOR PALISADES 1

SITE SOIL CATEGORY  SAND-2

S-XPT  HOST            ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION
NUM.   ZONE              AT LOW PGA(0.125G)                           AT HIGH PGA(0.60G)
----------------------------------------------------------------------------------------------------
 1  ZONE 15    ZONE ID: ZONE 9    ZONE 19    ZONE 11    ZONE 15       ZONE 9    ZONE 15    ZONE 19    ZONE 11
               % CONT.:      38.        22.        16.        12.          42.        41.        11.        4.
----------------------------------------------------------------------------------------------------
 2  COMP. ZO   ZONE ID: ZONE 18   COMP. ZON  ZONE 20    ZONE 21       COMP. ZON ZONE 18    ZONE 20    ZONE  6
               % CONT.:      69.        24.         6.         1.          51.        49.         0.        0.
----------------------------------------------------------------------------------------------------
 3  ZONE 15    ZONE ID: ZONE 15   ZONE 11    ZONE 13    ZONE 16       ZONE 15   COMP. ZON  ZONE 13    ZONE 16
               % CONT.:      85.         6.         3.         2.          99.         0.         0.        0.
----------------------------------------------------------------------------------------------------
 4  ZONE 13    ZONE ID: ZONE  4   ZONE  6    ZONE  5    ZONE 27       ZONE  4   ZONE 13    ZONE  6    ZONE 27
               % CONT.:      61.        18.         6.         5.          71.        26.         2.        1.
----------------------------------------------------------------------------------------------------
 5  COMP. ZO   ZONE ID: ZONE 12   ZONE 15    COMP. ZON  ZONE  6       ZONE 15   COMP. ZON  ZONE 12    ZONE  1
               % CONT.:      44.        41.         7.         5.          70.        25.         5.        0.
----------------------------------------------------------------------------------------------------
 6  COMP. ZO   ZONE ID: ZONE 22   ZONE 17    ZONE 9     COMP. ZON     ZONE 22   COMP. ZON  ZONE 17    ZONE 9
               % CONT.:      45.        22.        15.        14.          59.        34.         4.        2.
----------------------------------------------------------------------------------------------------
 7  ZONE 2 =   ZONE ID: ZONE 6    ZONE 2 =   ZONE 5     ZONE 34       ZONE 6    ZONE 2 =   ZONE 3     ZONE 5
               % CONT.:      76.        16.         3.         1.          59.        40.         0.        0.
----------------------------------------------------------------------------------------------------
10  ZONE  27   ZONE ID: ZONE 26A  ZONE  27   ZONE 12A   ZONE 19 =     ZONE  27  ZONE 19 =  ZONE 26A   ZONE  4B
               % CONT.:      54.        34.         7.         5.          80.        16.         4.        0.
----------------------------------------------------------------------------------------------------
11  CZ = ZON   ZONE ID: CZ = ZONE ZONE 10    ZONE 11    ZONE  9       CZ = ZONE ZONE 10    ZONE 11    ZONE  9
               % CONT.:      85.        11.         2.         2.         100.         0.         0.        0.
----------------------------------------------------------------------------------------------------
12  ZONE 4 =   ZONE ID: ZONE 15   ZONE 13    ZONE 14    ZONE 31A      ZONE 15   ZONE 6     ZONE 7     ZONE 12
               % CONT.:      52.        14.        13.         9.         100.         0.         0.        0.
----------------------------------------------------------------------------------------------------
13  CZ 15      ZONE ID: CZ 15     ZONE  5    ZONE  6    ZONE  7       CZ 15     ZONE  5    ZONE  3    ZONE  4
               % CONT.:      89.         9.         1.         0.          99.         1.         0.        0.
----------------------------------------------------------------------------------------------------
```

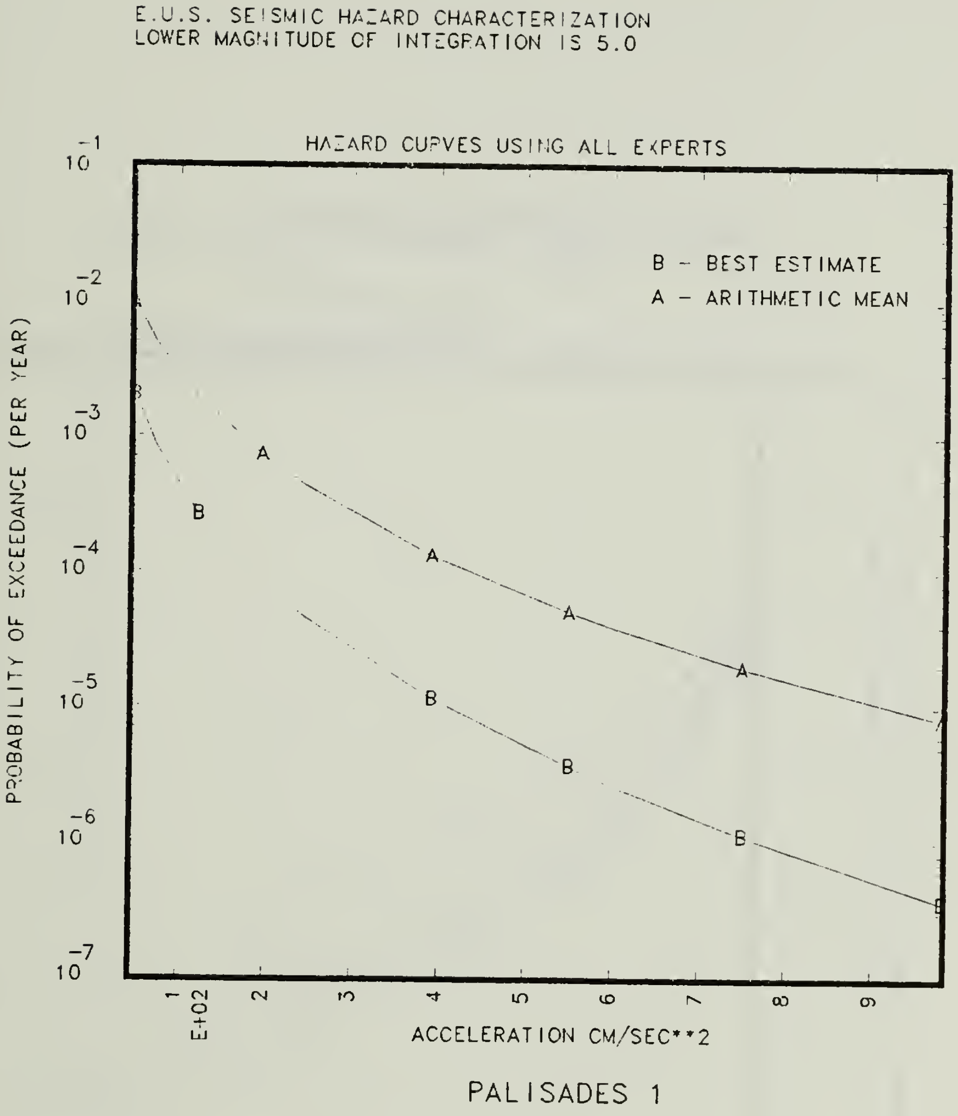


Figure 2.12.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Palisades site.

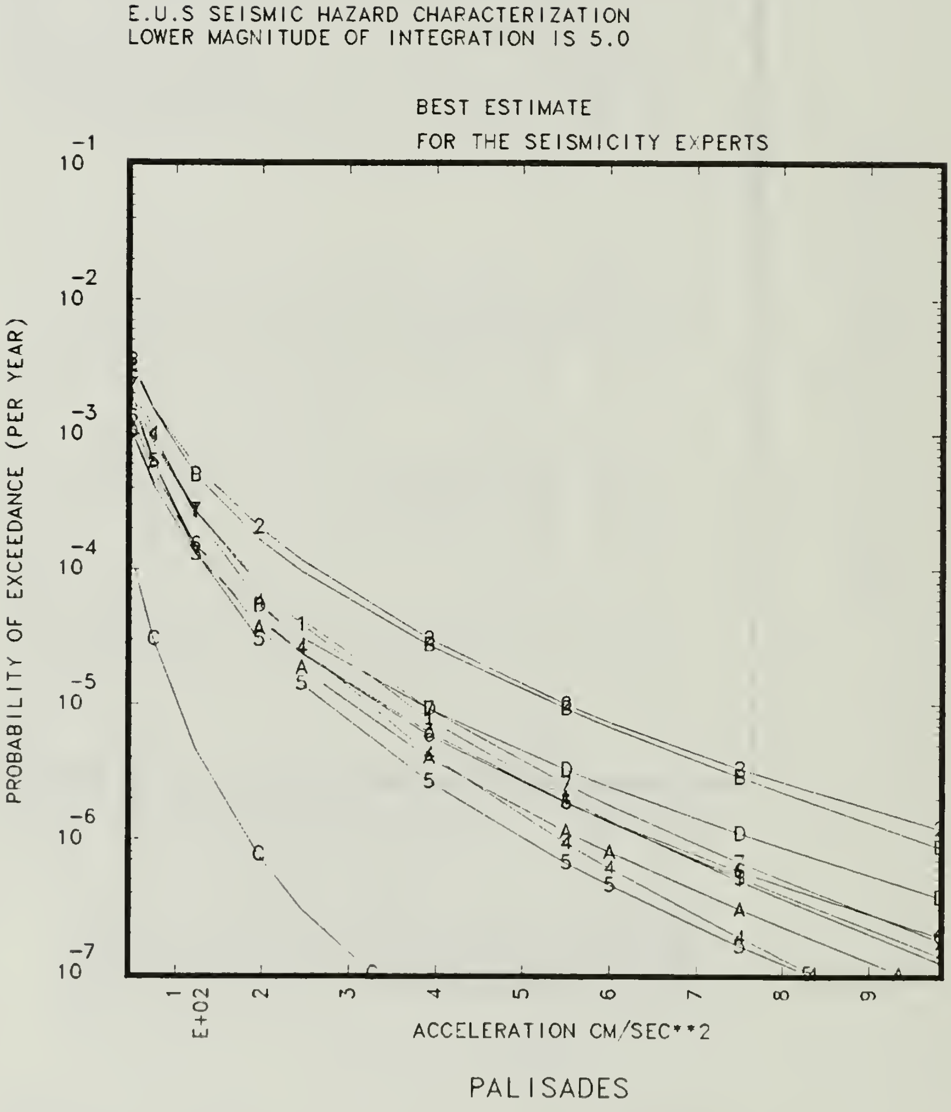


Figure 2.12.2 BEHCs per S-Expert combined over all G-Experts for the Palisades site. Plot symbols given in Table 2.0.

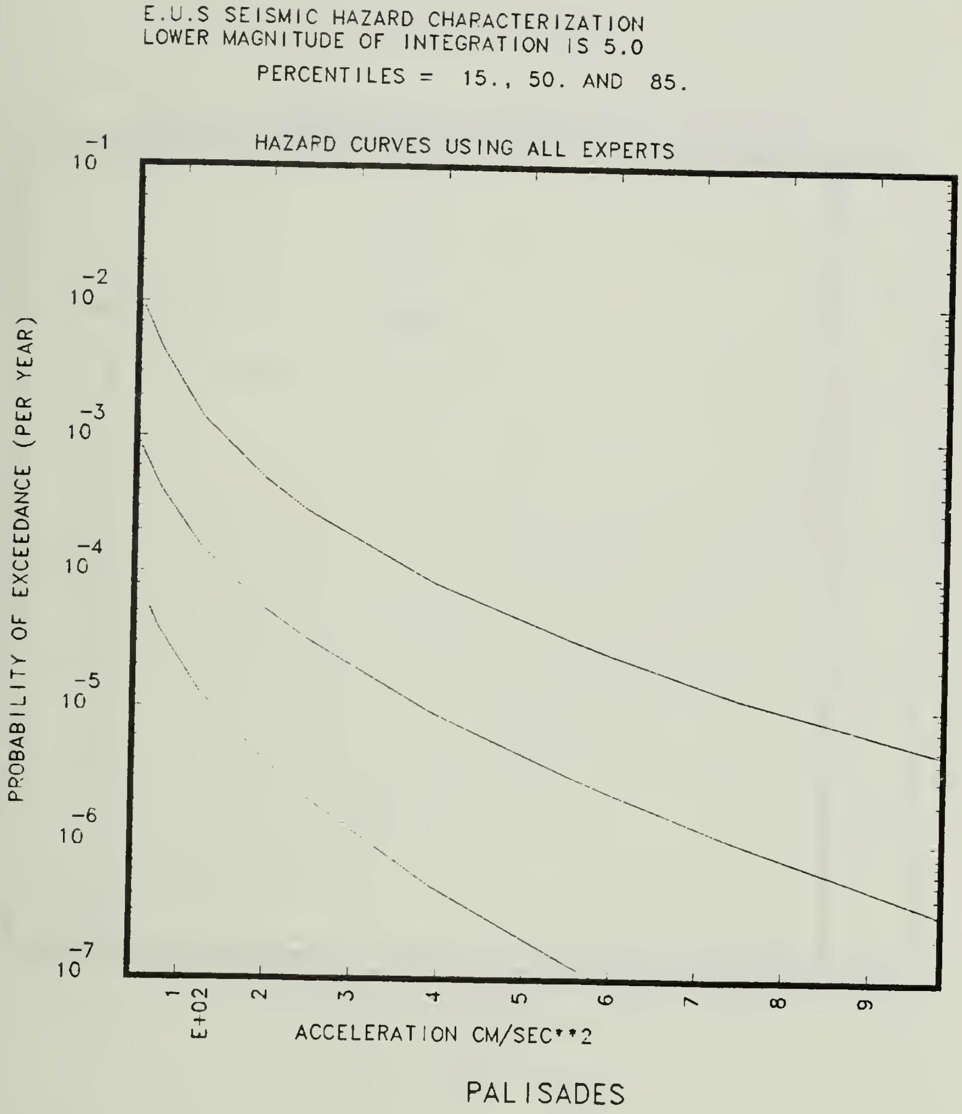


Figure 2.12.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Palisades site.

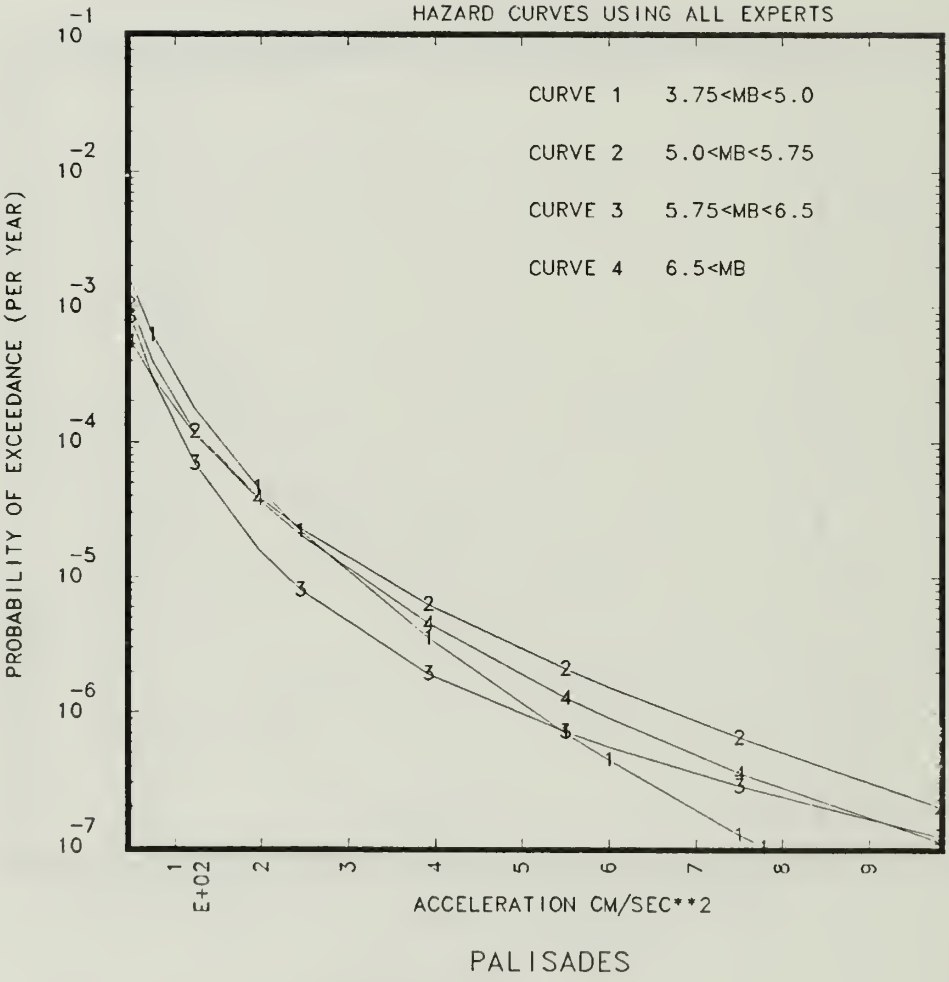
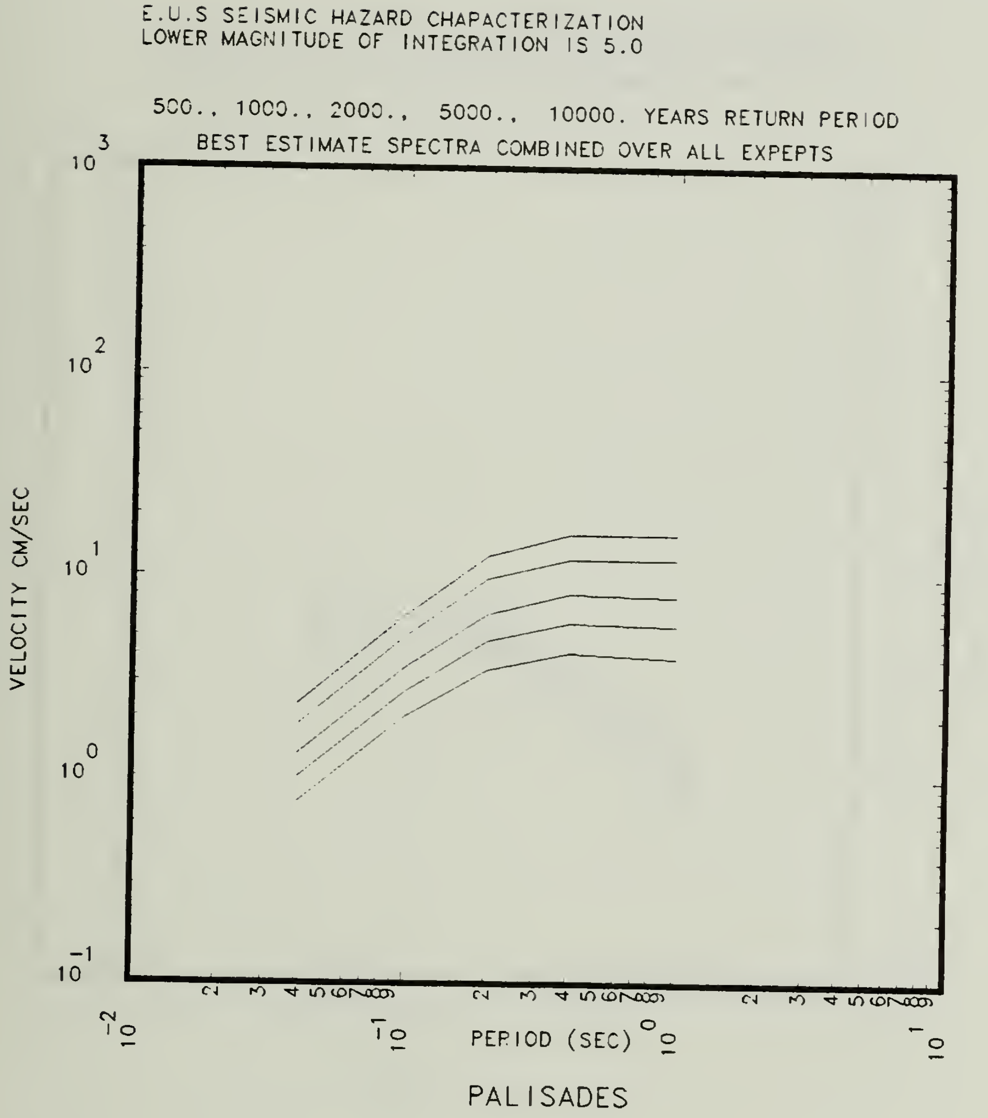


Figure 2.12.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Palisades site.



igure 2.12.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Palisades site.

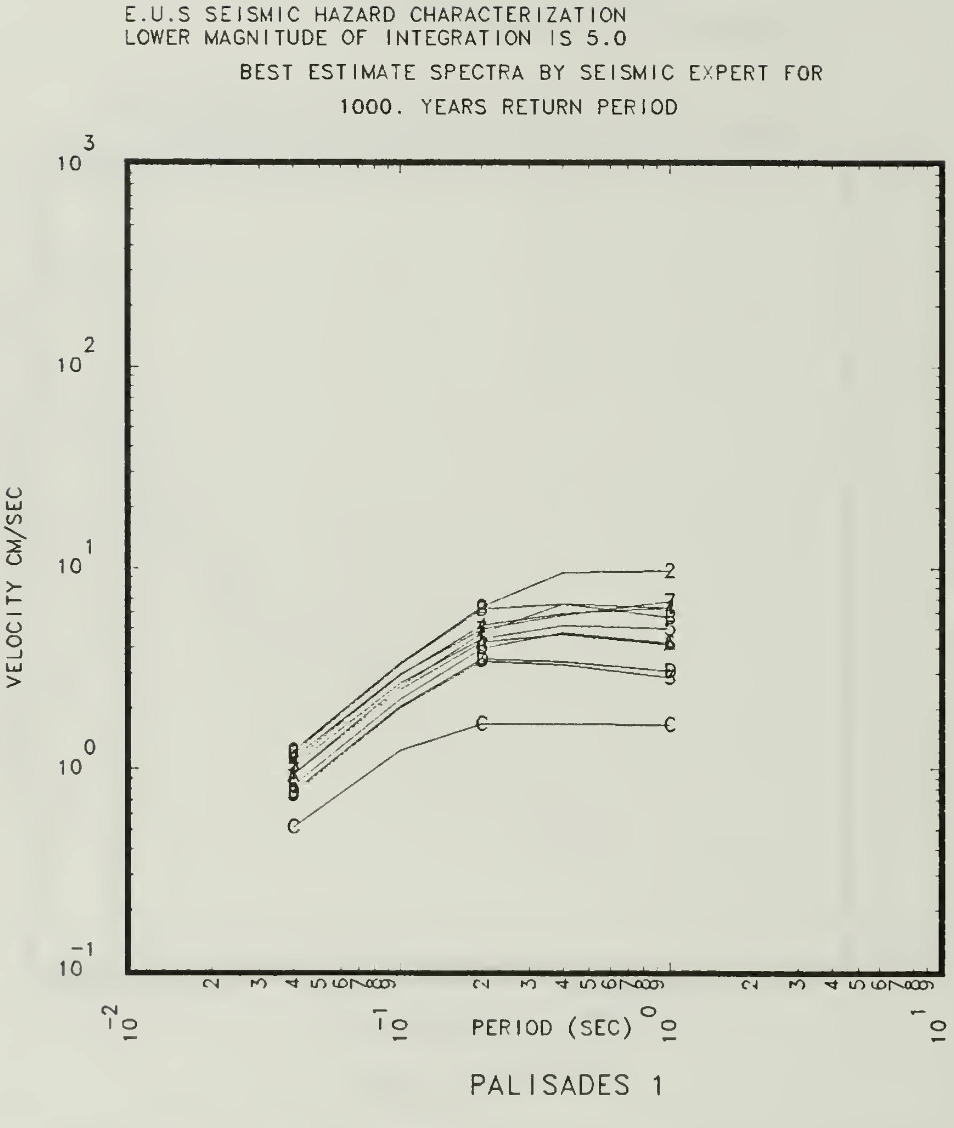
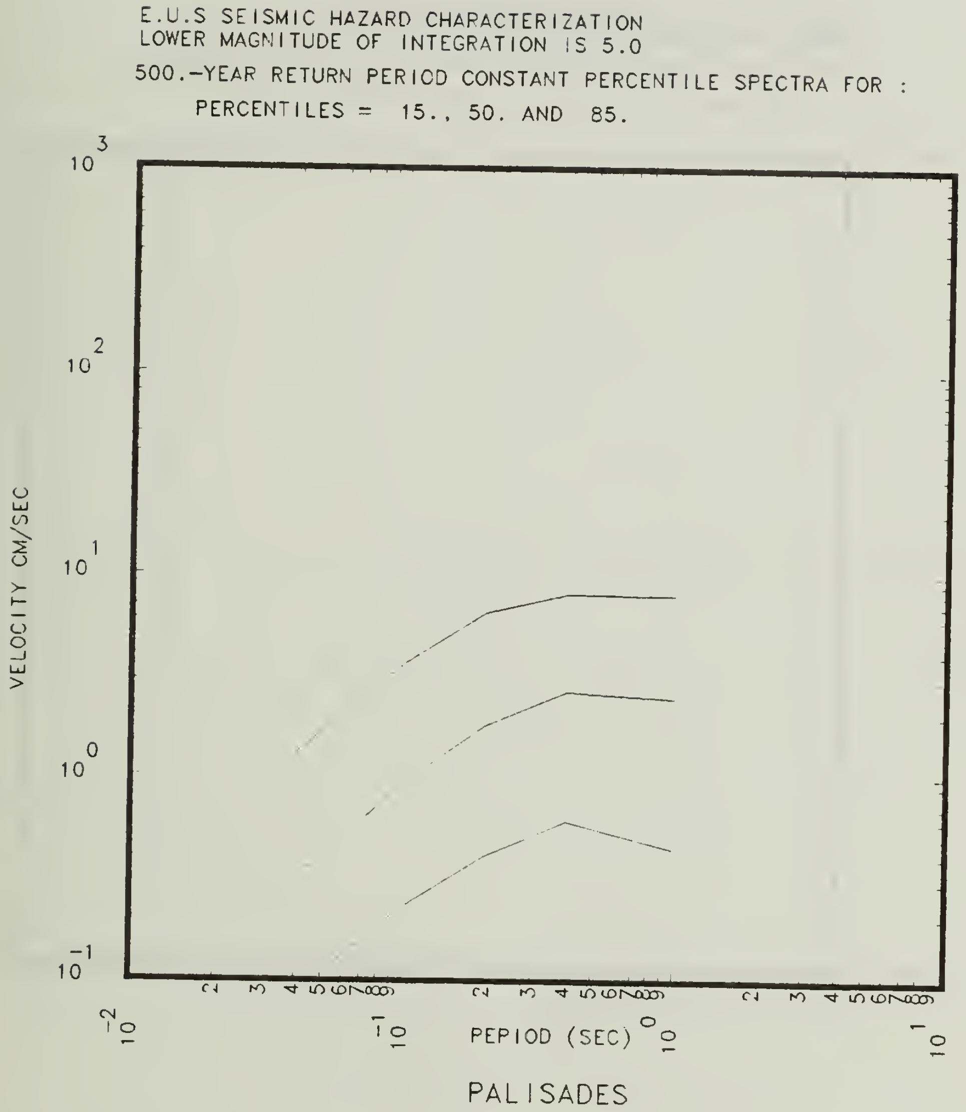


Figure 2.12.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Palisades site. Plot symbols are given in Table 2.0.



gure 2.12.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Palisades site.

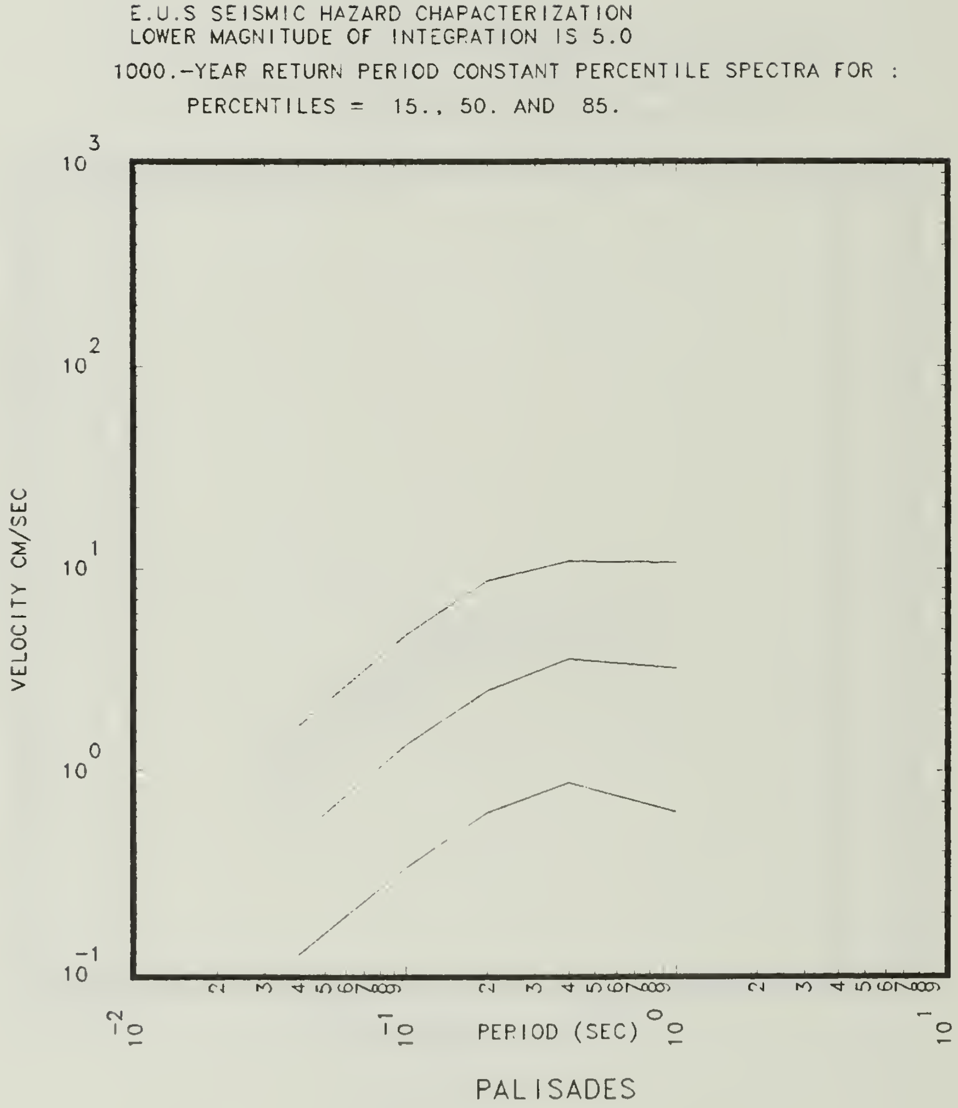


Figure 2.12.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Palisades site.

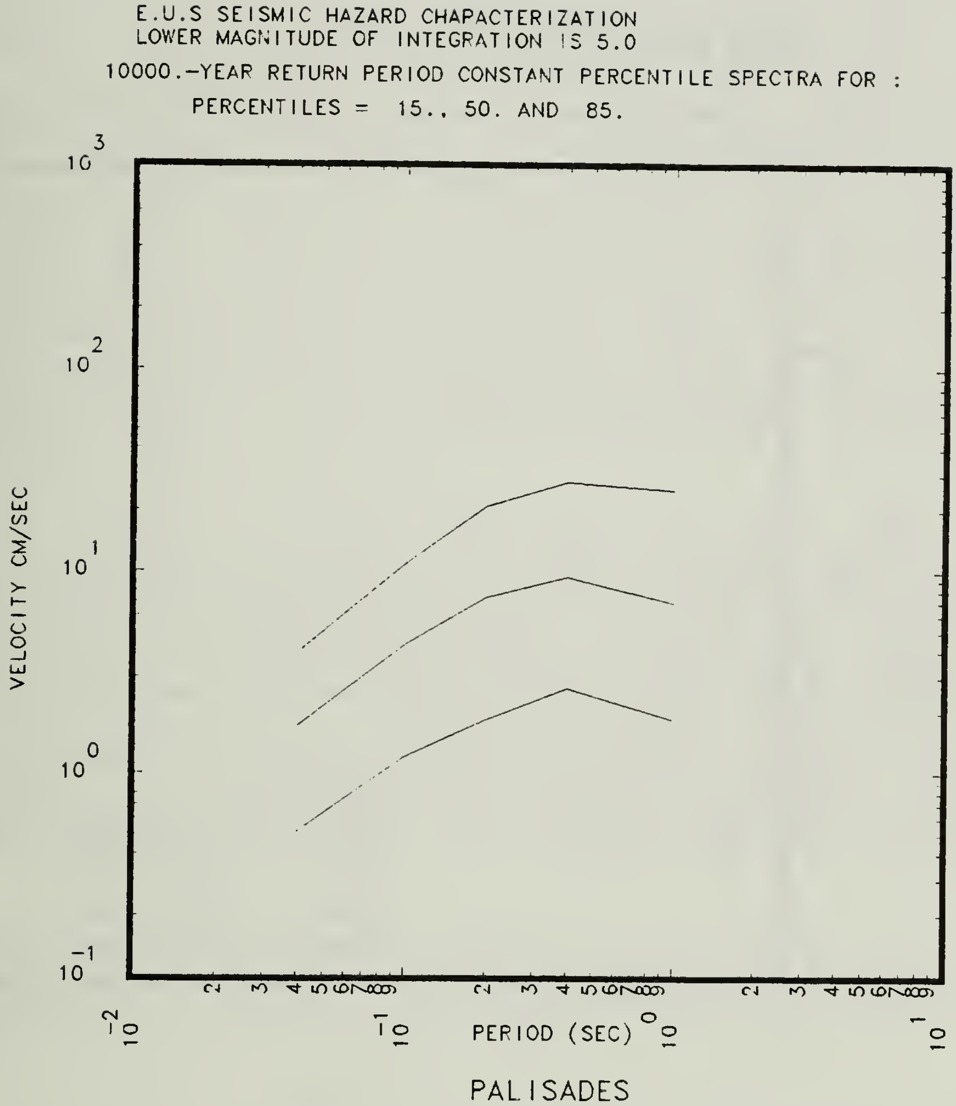


Figure 2.12.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Palisades site.

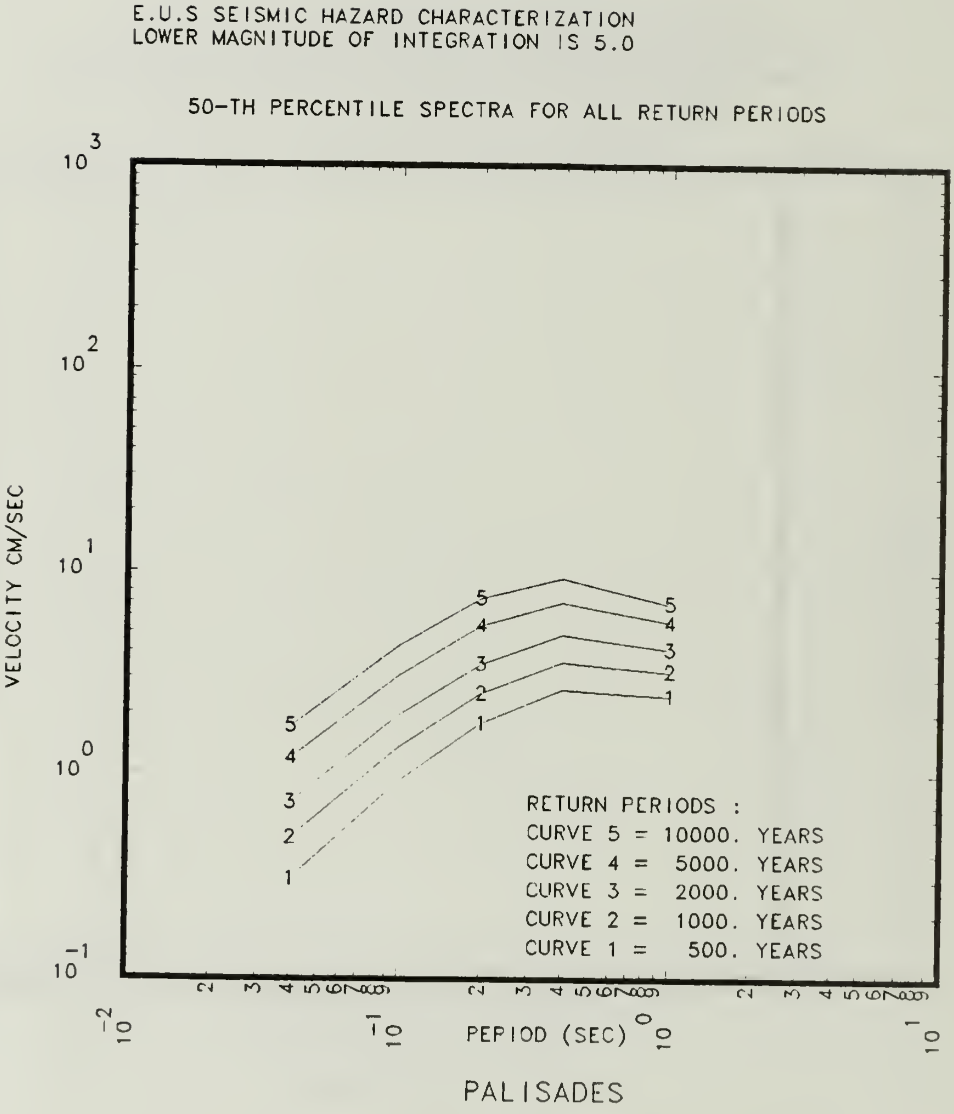


Figure 2.12.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Palisades site.

2.13 PERRY

The Perry site is a rock site and it is represented by the symbol "D" in Fig. 1.1. Table 2.13.1 and Figs. 2.13.1 through 2.13.10 give the basic results for the Perry site.

The spread between the AMHC and the BEHC is typical for rock sites in region 3. The AMHC is equal to the 85th percentile CPHC at the low g-value end but higher at the high g-value end.

We see from Table 2.13.1 that for S-Experts 1, 3, 4, 6, 10, 11 and 13 that the host zone contributes most to the BEHC for PGA. For these S-Experts the spread between the G-Experts' BEHC is similar to the spread shown in Fig. 2.3.11. For S-Experts 2 and 7, where distant zones with large magnitudes earthquakes play a relatively important role (33 percent contribution for S-Expert 2 and 45 percent for S-Expert 7), the spread between G-Expert 5's BEHC and the other G-Experts' BEHCs is somewhat larger than shown in Fig. 2.3.11 but less than shown in Fig. 2.3.12. Note from Table 2.3.1 that for the Braidwood site for S-Experts 2 and 7 the New Madrid zones contributed over 80 percent of the hazard hence the spread between G-Expert 5's BEHC and to other G-Experts' BEHC is larger than at the Perry site where distant zones with large earthquakes contribute less to the BEHC for PGA. However, at the Perry site for S-Expert 12 the distant zones 14 and 15 around New Madrid contribute 75 percent of the hazard hence the spread between G-Expert 5's BEHC and the other G-Experts' BEHC for the Perry site for S-Expert 12's input is large and similar to that shown in Fig. 2.3.13.

The case for S-Expert 5 is somewhat more complex. We see from Fig. 2.13.2 that S-Expert 5's BEHC cross all of the S-Expert's BEHCs. This is because S-Expert 5's BEHC for the Perry site is controlled by two somewhat distant zones--zones 6 and 12--which have high rates of activity but a relatively low upper magnitude cutoff, at least when compared to the New Madrid zones of S-Experts 2 and 12. Because zones 6 and 12 for S-Expert 5 have a much higher rate than other zones closer to the Perry site G-Expert's BE GM model dominates because, as discussed in Section 2.3 of the low attenuation and site correction term. For this case the spread between the G-Experts' BEHC is similar to that shown in Fig. 2.3.13 except at the higher g-loads G-Expert 5's BEHC for S-Expert 5's input for the Perry site parallels the other G-Experts' BEHCs.

We see from Fig. 2.13.4 that if earthquakes in the magnitude range 3.75 to 5 were included in the analysis, the BEHC for PGA would only be increased in the 0.05g to 0.2g range.

TABLE 2.13.1

MOST IMPORTANT ZONES PER S-EXPERT FOR PERRY

SITE SOIL CATEGORY ROCK

S-XPT NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 19	ZONE ID:	ZONE 19	ZONE 4	ZONE 20	ZONE 9	ZONE 19	ZONE 9	ZONE 4	ZONE 15
		% CONT.:	70.	12.	6.	4.	97.	2.	1.	0.
2	COMP. ZO	ZONE ID:	ZONE 18	COMP. ZON	ZONE 32	ZONE 27	COMP. ZON	ZONE 18	ZONE 32	ZONE 27
		% CONT.:	38.	33.	13.	6.	62.	33.	5.	0.
3	ZONE 11	ZONE ID:	ZONE 11	ZONE 2	ZONE 5	ZONE 15	ZONE 11	COMP. ZON	ZONE 13	ZONE 2
		% CONT.:	97.	1.	1.	0.	100.	0.	0.	0.
4	ZONE 27	ZONE ID:	ZONE 27	ZONE 16	ZONE 4	ZONE 7	ZONE 27	ZONE 4	ZONE 16	ZONE 13
		% CONT.:	80.	6.	4.	3.	99.	1.	0.	0.
5	COMP. ZO	ZONE ID:	ZONE 6	ZONE 12	ZONE 15	ZONE 5	ZONE 6	ZONE 12	ZONE 15	COMP. ZON
		% CONT.:	77.	18.	2.	2.	53.	26.	12.	6.
6	ZONE 10	ZONE ID:	ZONE 10	ZONE 9	ZONE 7	ZONE 8	ZONE 10	ZONE 9	ZONE 8	ZONE 7
		% CONT.:	42.	24.	10.	8.	80.	15.	2.	1.
7	ZONE 2 =	ZONE ID:	ZONE 6	ZONE 41	ZONE 2 =	ZONE 7	ZONE 6	ZONE 2 =	ZONE 41	ZONE 7
		% CONT.:	35.	18.	13.	12.	45.	41.	13.	1.
10	ZONE 26A	ZONE ID:	ZONE 26A	ZONE 19 =	ZONE 10	ZONE 9	ZONE 26A	ZONE 19 =	ZONE 10	ZONE 9
		% CONT.:	76.	14.	4.	2.	97.	3.	0.	0.
11	ZONE 9	ZONE ID:	ZONE 9	CZ = ZONE	ZONE 5	ZONE 3	ZONE 9	CZ = ZONE	ZONE 5	ZONE 3
		% CONT.:	82.	6.	5.	3.	98.	1.	0.	0.
12	ZONE 4 =	ZONE ID:	ZONE 31	ZONE 31A	ZONE 18	ZONE 19	ZONE 18	ZONE 15	ZONE 31	ZONE 14
		% CONT.:	58.	14.	12.	4.	68.	32.	0.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 7	ZONE 11	ZONE 8	CZ 15	ZONE 5	ZONE 3	ZONE 4
		% CONT.:	89.	4.	3.	2.	100.	0.	0.	0.

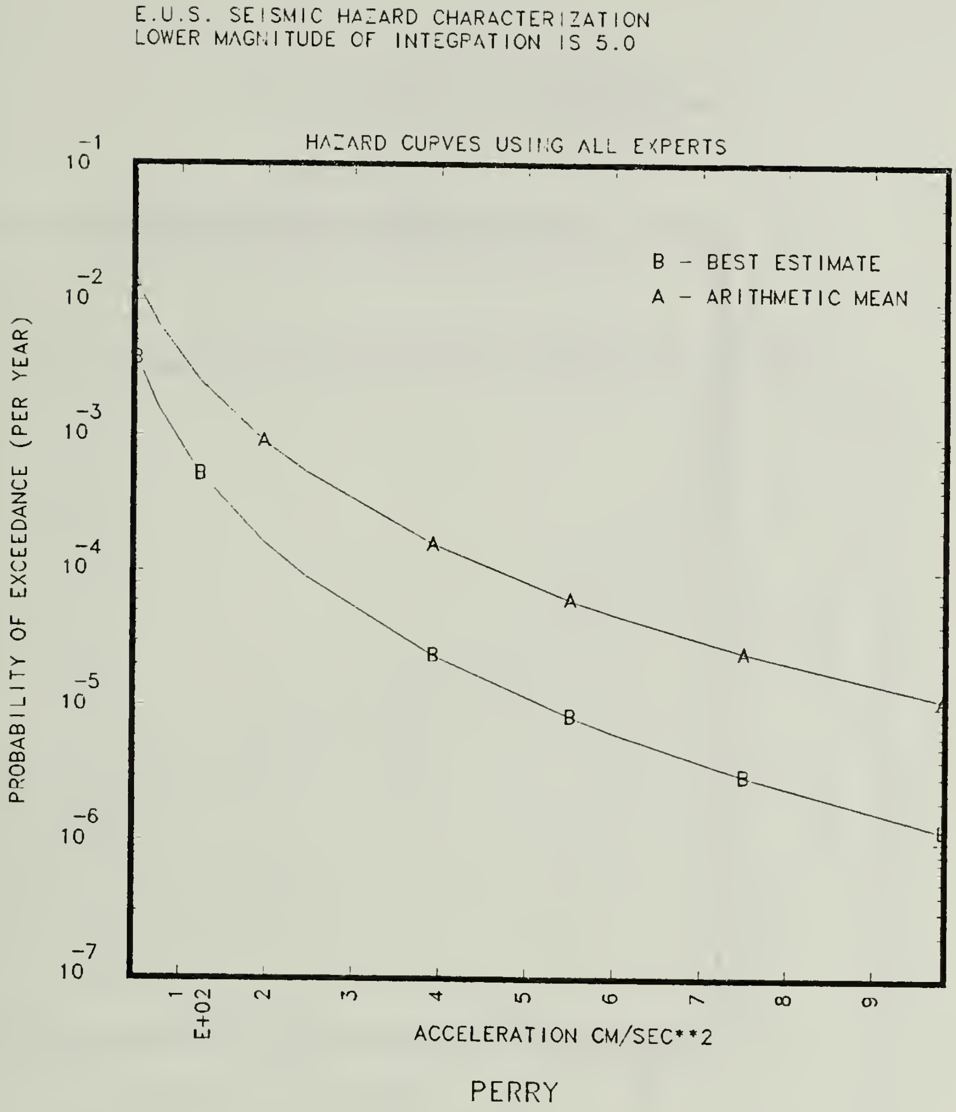


Figure 2.13.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Perry site.

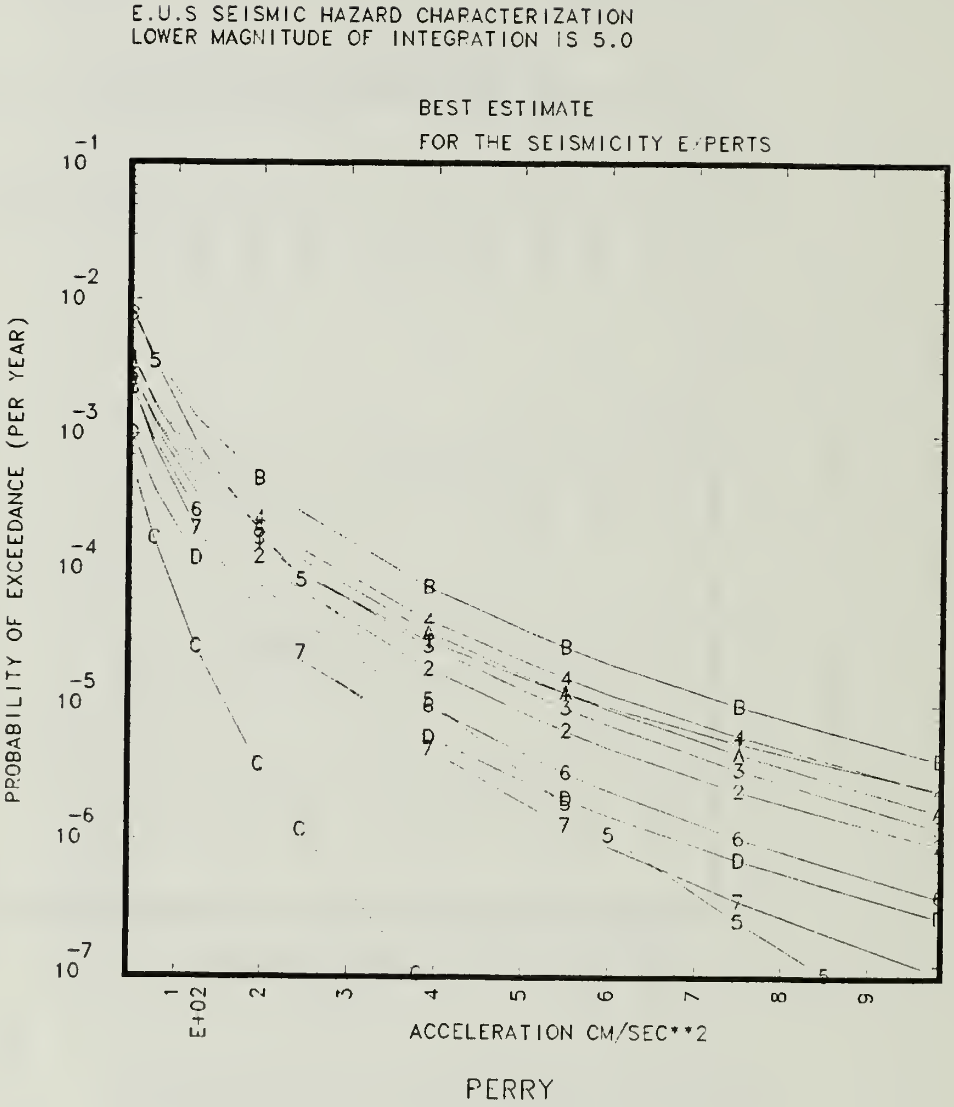


Figure 2.13.2 BEHCs per S-Expert combined over all G-Experts for the Perry site. Plot symbols given in Table 2.0.

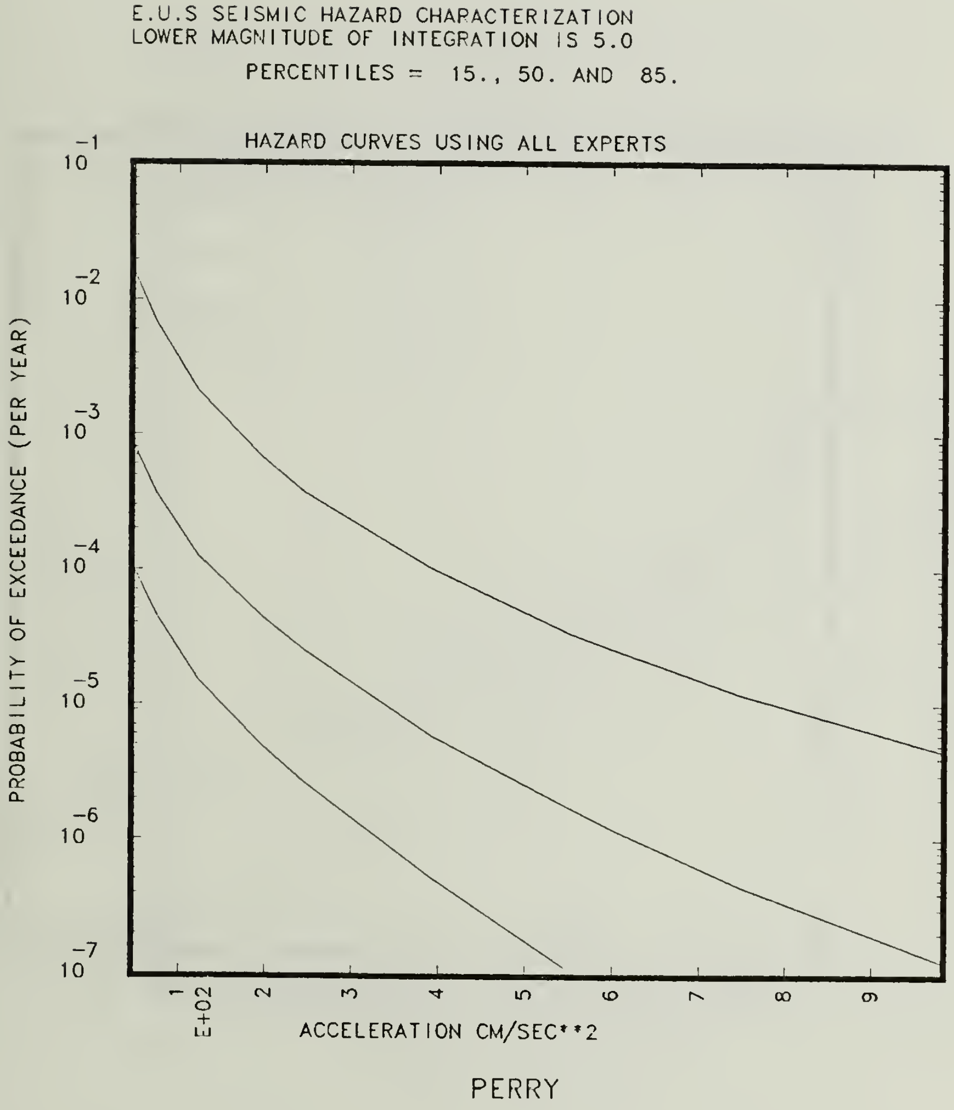


Figure 2.13.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Perry site.

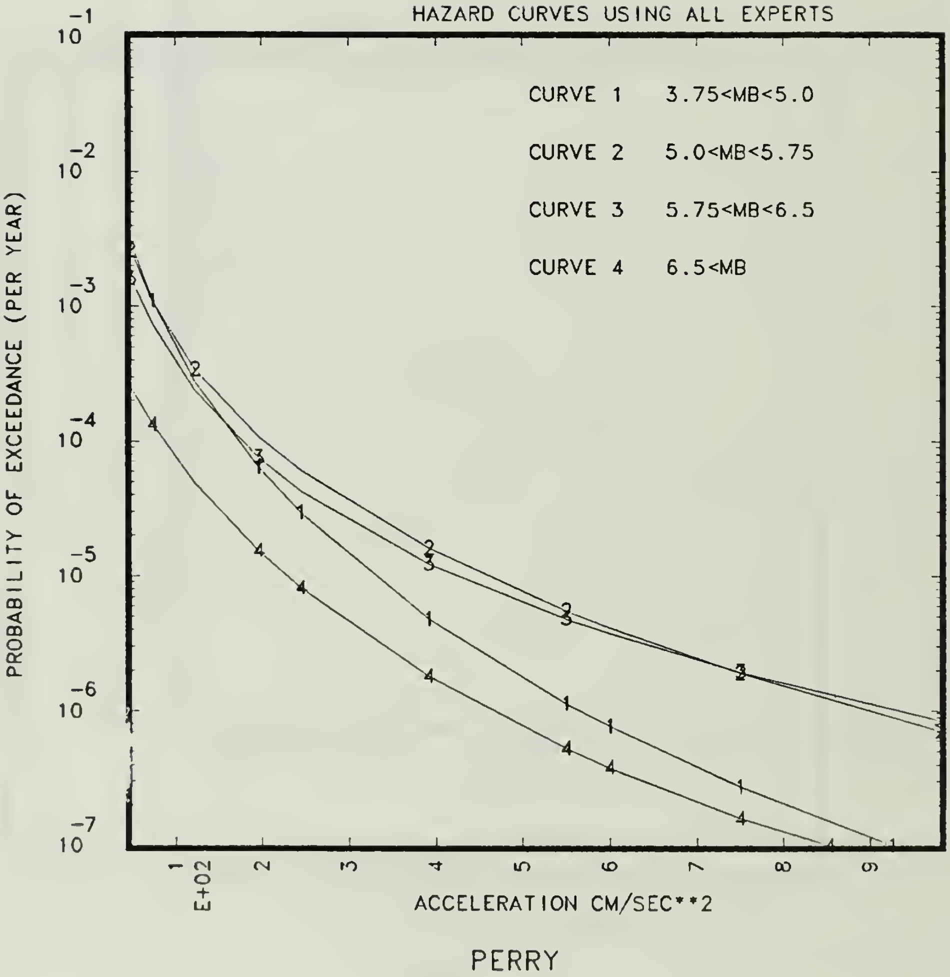


Figure 2.13.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Perry site.

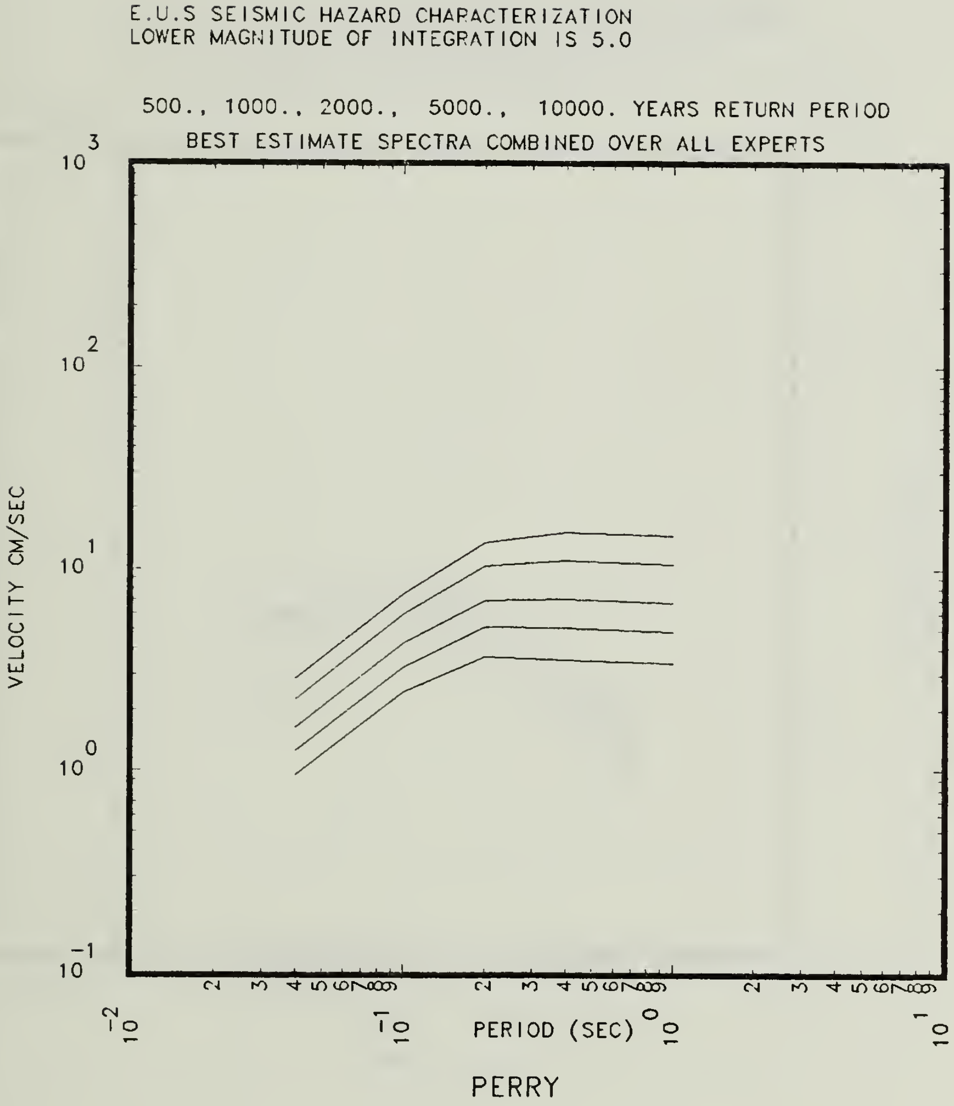


Figure 2.13.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Perry site.

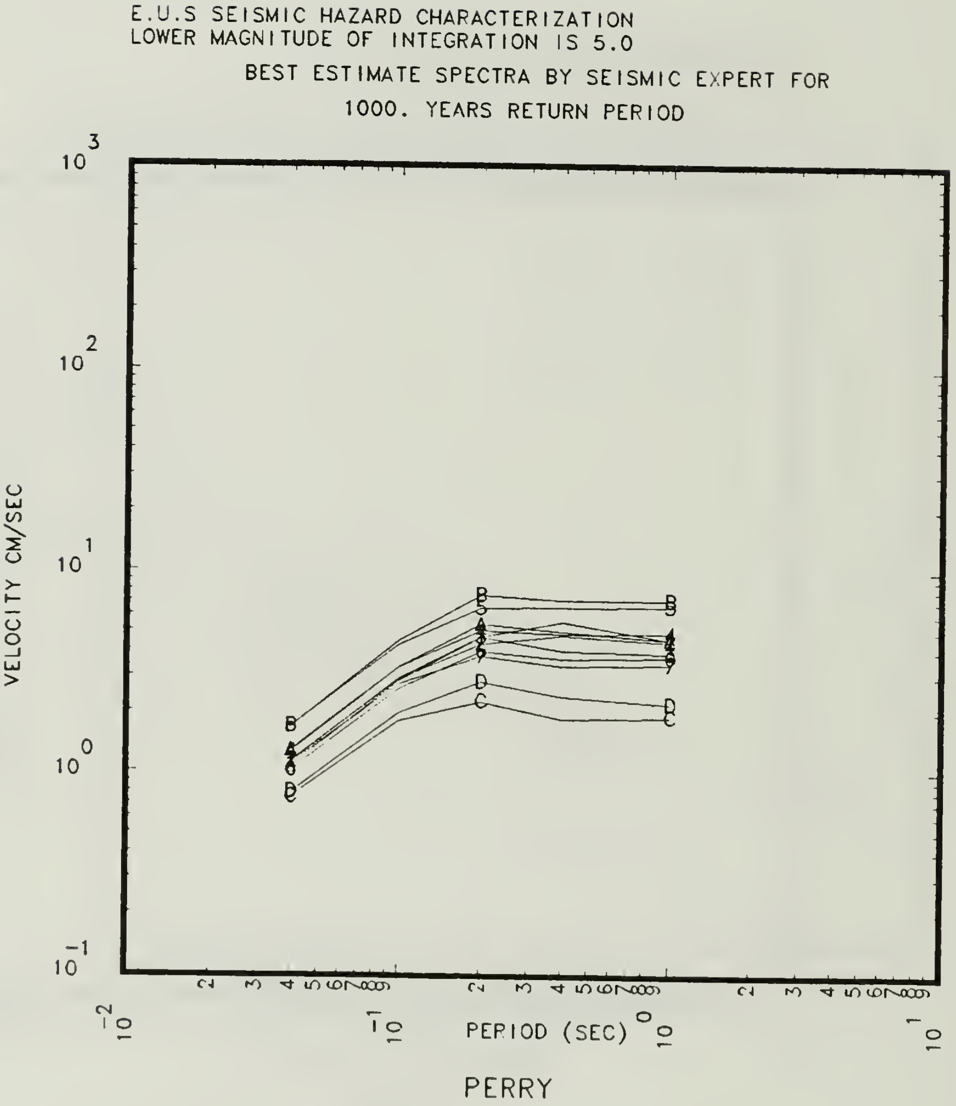


Figure 2.13.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Perry site. Plot symbols are given in Table 2.0.

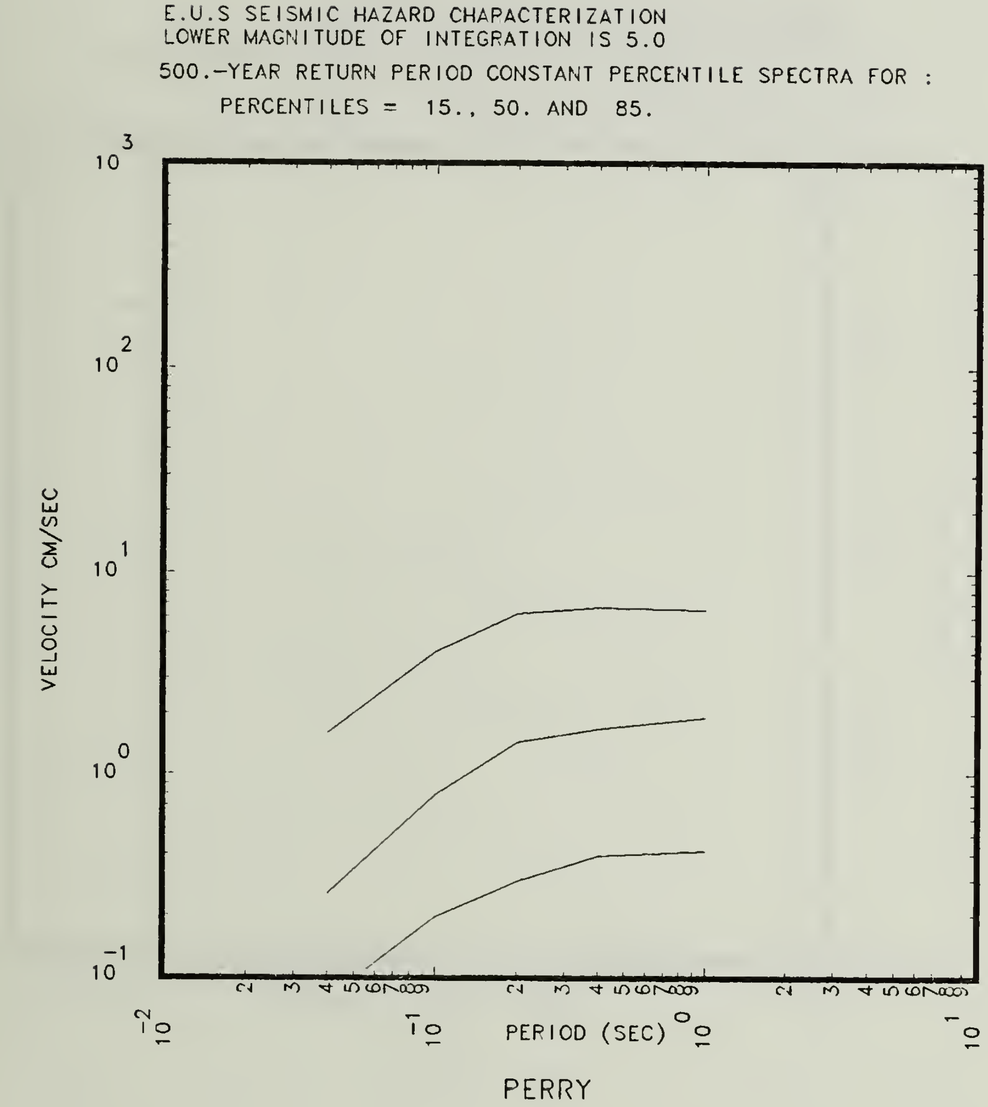


Figure 2.13.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Perry site.

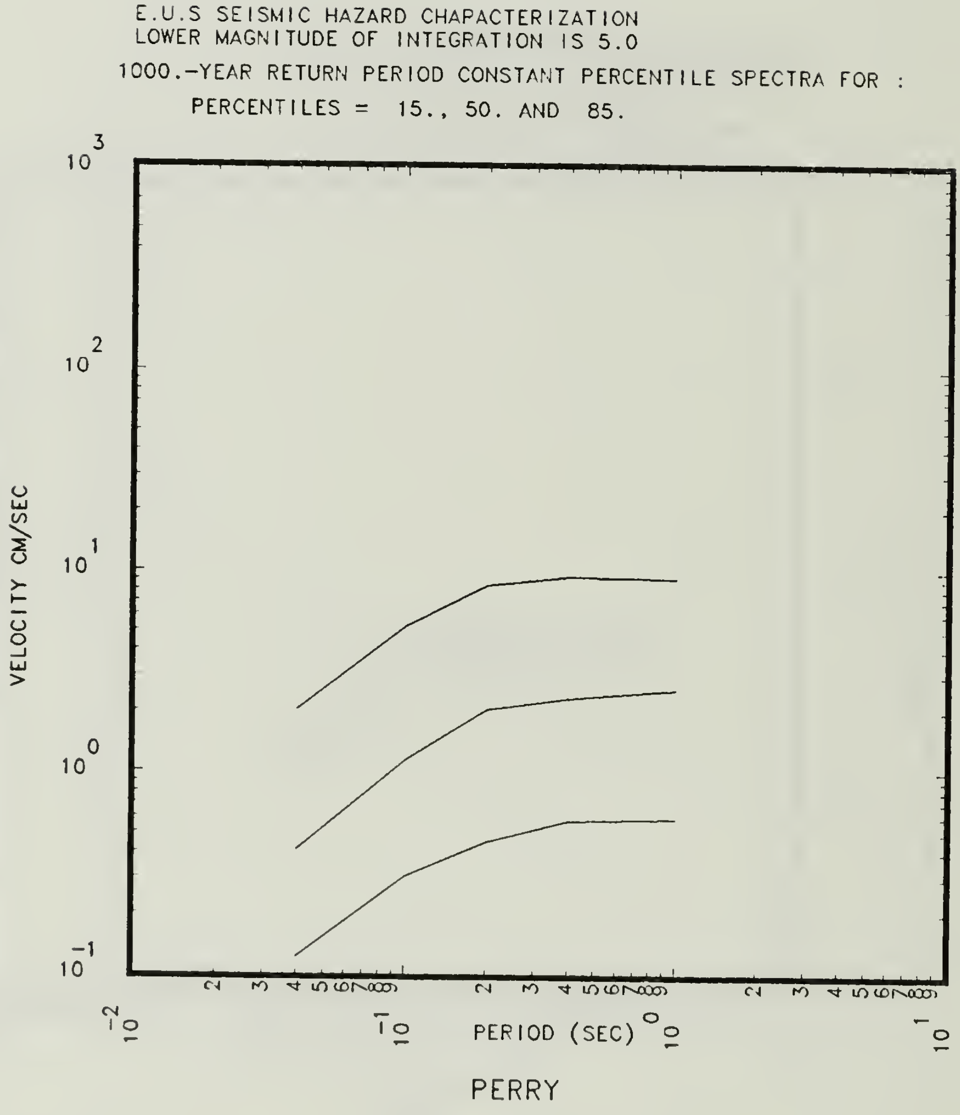


Figure 2.13.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Perry site.

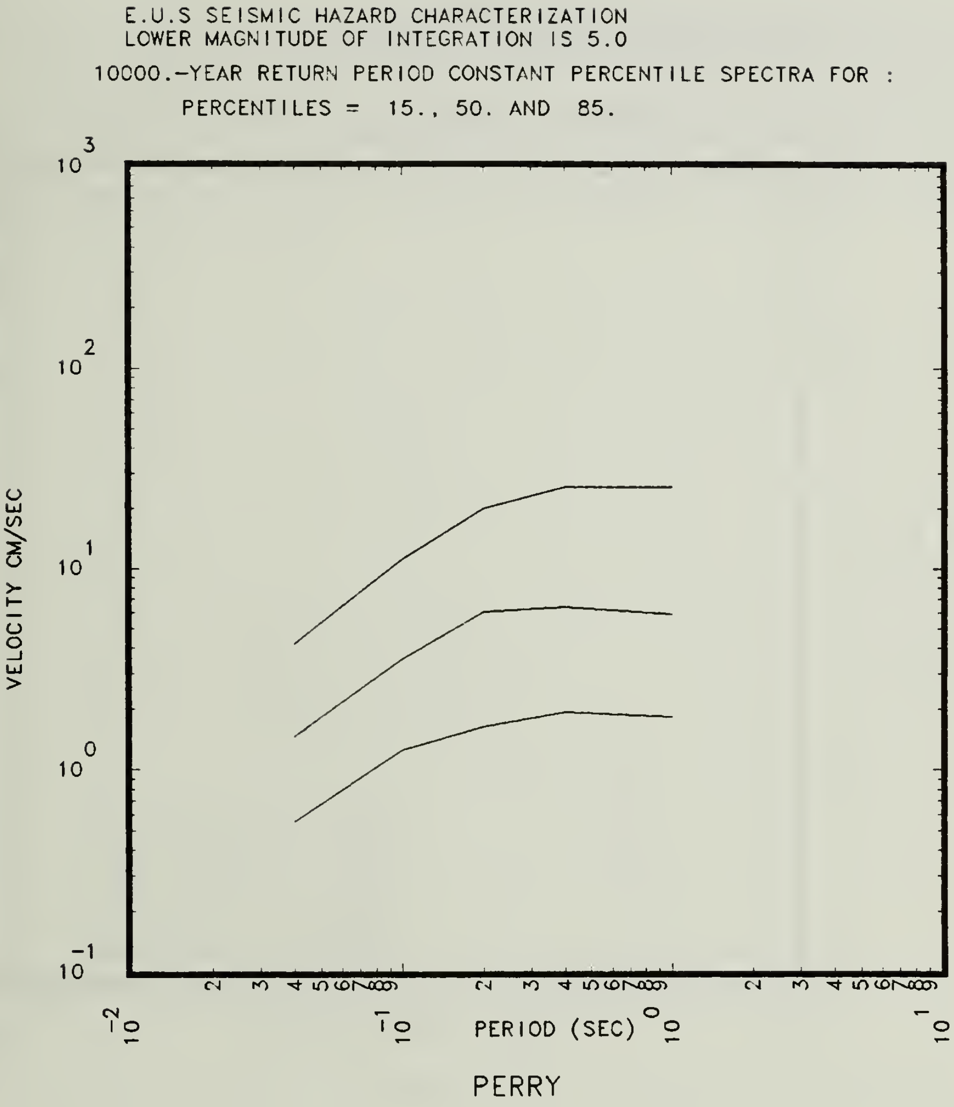


Figure 2.13.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Perry site.

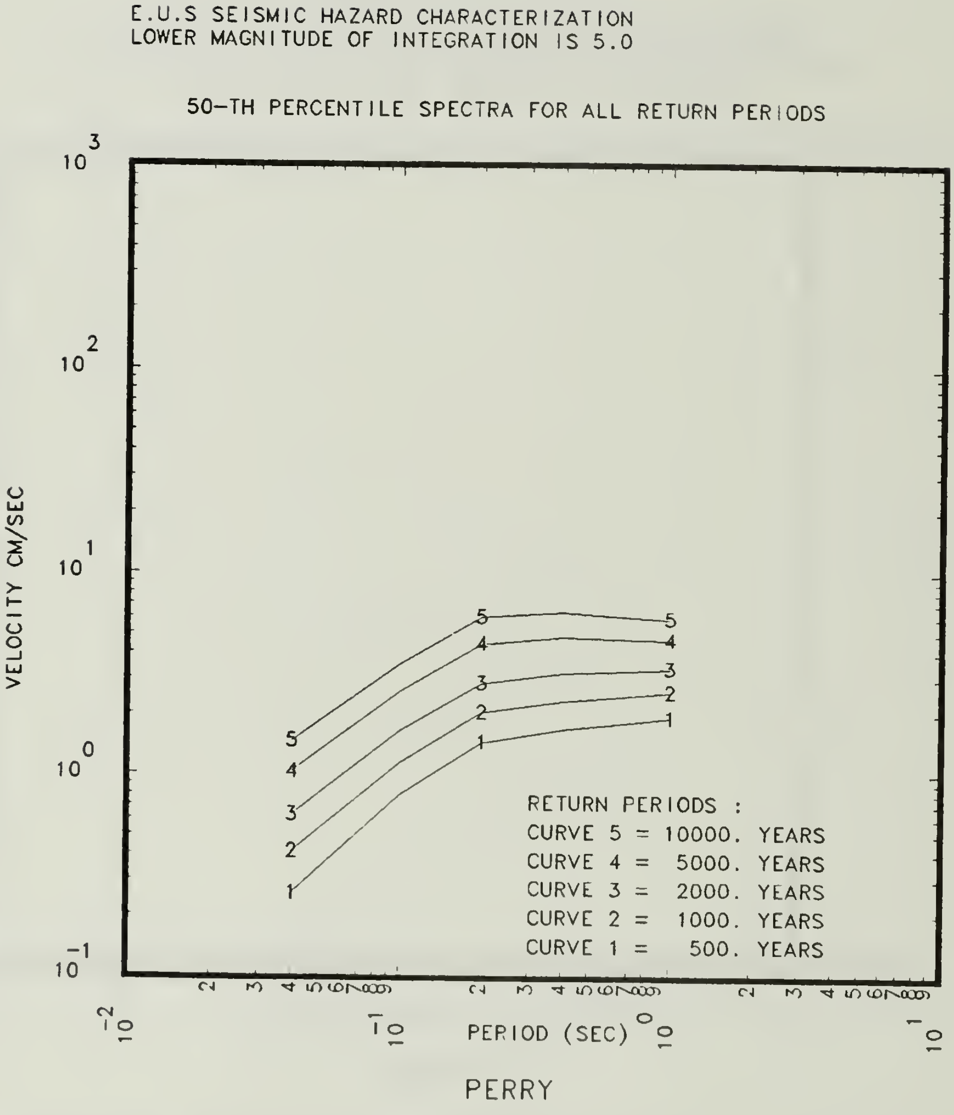


Figure 2.13.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Perry site.

2.14 POINT BEACH

The Point Beach site's soil category is till-like 1 and it is represented by the symbol "E" on Fig. 1.1. Table 2.14.1 and Figs. 2.14.1 through 2.14.10 give the basic results for the Point Beach site.

We see from Fig. 1.1 that the Point Beach site is very near the Kewaunee site. Although there is a difference between the soil category for the two sites (Kewaunee is till-like 2 category) the discussion given for the Kewaunee site in Section 2.10 holds and is not repeated here.

The differences in the site's soil category can be seen by comparing Fig. 2.14.5 or 2.14.7 to 2.10.5 or 2.10.7. The significance of the site's soil category is discussed in detail in Vol. VI. The dip observed in the median spectrum in Fig. 2.14.7 is consistent with the shape of the median spectrum for Kewaunee (Fig. 2.10.7), acknowledging the fact that Kewaunee is a till-1 site and Point Beach is Till-2. The soil amplification is indeed higher for the till-2 (Kewaunee) than for till-1, at 0.4 second period, and it is not so different for the other period.

TABLE 2.14.1

```
                         MOST IMPORTANT ZONES PER S-EXPERT
                                 FOR POINT BEACH

SITE SOIL CATEGORY  TILL-1

S-XPT  HOST              ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION
NUM.   ZONE                AT LOW PGA(0.125G)                                AT HIGH PGA(0.60G)
----------------------------------------------------------------------------------------------------------------
 1   ZONE 15     ZONE ID: ZONE 15    ZONE 9     ZONE 11    ZONE 10         ZONE 15    ZONE 9     ZONE 11    ZONE 19
                 % CONT.:       34.        33.        15.        11.              80.        18.         1.         0.
----------------------------------------------------------------------------------------------------------------
 2   COMP. ZO    ZONE ID: ZONE 18    COMP. ZON ZONE 20    ZONE 21         COMP. ZON ZONE 18    ZONE 13    ZONE 15
                 % CONT.:       48.        48.         2.         1.              84.        16.         0.         0.
----------------------------------------------------------------------------------------------------------------
 3   COMP. ZO    ZONE ID: COMP. ZON ZONE 15    ZONE 13    ZONE 12         COMP. ZON ZONE 13    ZONE 15    ZONE 2
                 % CONT.:       81.        10.         3.         2.             100.         0.         0.         0.
----------------------------------------------------------------------------------------------------------------
 4   ZONE 13     ZONE ID: ZONE  4    ZONE  6    ZONE 13    ZONE  5         ZONE 13    ZONE  4    ZONE  6    COMP. ZON
                 % CONT.:       44.        35.        13.         4.              67.        27.         6.         1.
----------------------------------------------------------------------------------------------------------------
 5   COMP. ZO    ZONE ID: ZONE 15    COMP. ZON ZONE 13    ZONE 12         COMP. ZON ZONE 15    ZONE  4    ZONE  6
                 % CONT.:       44.        25.        16.         9.              66.        34.         0.         0.
----------------------------------------------------------------------------------------------------------------
 6   COMP. ZO    ZONE ID: COMP. ZON ZONE 22    ZONE 17    ZONE 7          COMP. ZON ZONE 22    ZONE 17    ZONE 18
                 % CONT.:       56.        20.        15.         4.              96.         3.         1.         0.
----------------------------------------------------------------------------------------------------------------
 7   ZONE 3      ZONE ID: ZONE 6     ZONE 3     ZONE 5     ZONE 4          ZONE 3     ZONE 6     ZONE 2 =   ZONE 4
                 % CONT.:       64.        32.         1.         1.              78.        21.         1.         0.
----------------------------------------------------------------------------------------------------------------
10   ZONE  27    ZONE ID: ZONE 19 = ZONE  27   ZONE 26A   ZONE 12A        ZONE  27   ZONE 19 = ZONE 26A   ZONE   5
                 % CONT.:       74.        21.         3.         1.              62.        38.         0.         0.
----------------------------------------------------------------------------------------------------------------
11   CZ = ZON    ZONE ID: CZ = ZONE ZONE 10    ZONE 11    ZONE  9         CZ = ZONE ZONE  2    ZONE  5    ZONE  6
                 % CONT.:       97.         3.         1.         0.             100.         0.         0.         0.
----------------------------------------------------------------------------------------------------------------
12   ZONE 4 =    ZONE ID: ZONE 31A   ZONE 15    ZONE 31    ZONE 13         ZONE 15    ZONE 5     ZONE 6     ZONE 7
                 % CONT.:       46.        23.        22.         5.             100.         0.         0.         0.
----------------------------------------------------------------------------------------------------------------
13   CZ 15       ZONE ID: CZ 15      ZONE  5    ZONE  6    ZONE 11         CZ 15      ZONE  5    ZONE  3    ZONE  4
                 % CONT.:       97.         3.         0.         0.             100.         0.         0.         0.
----------------------------------------------------------------------------------------------------------------
```

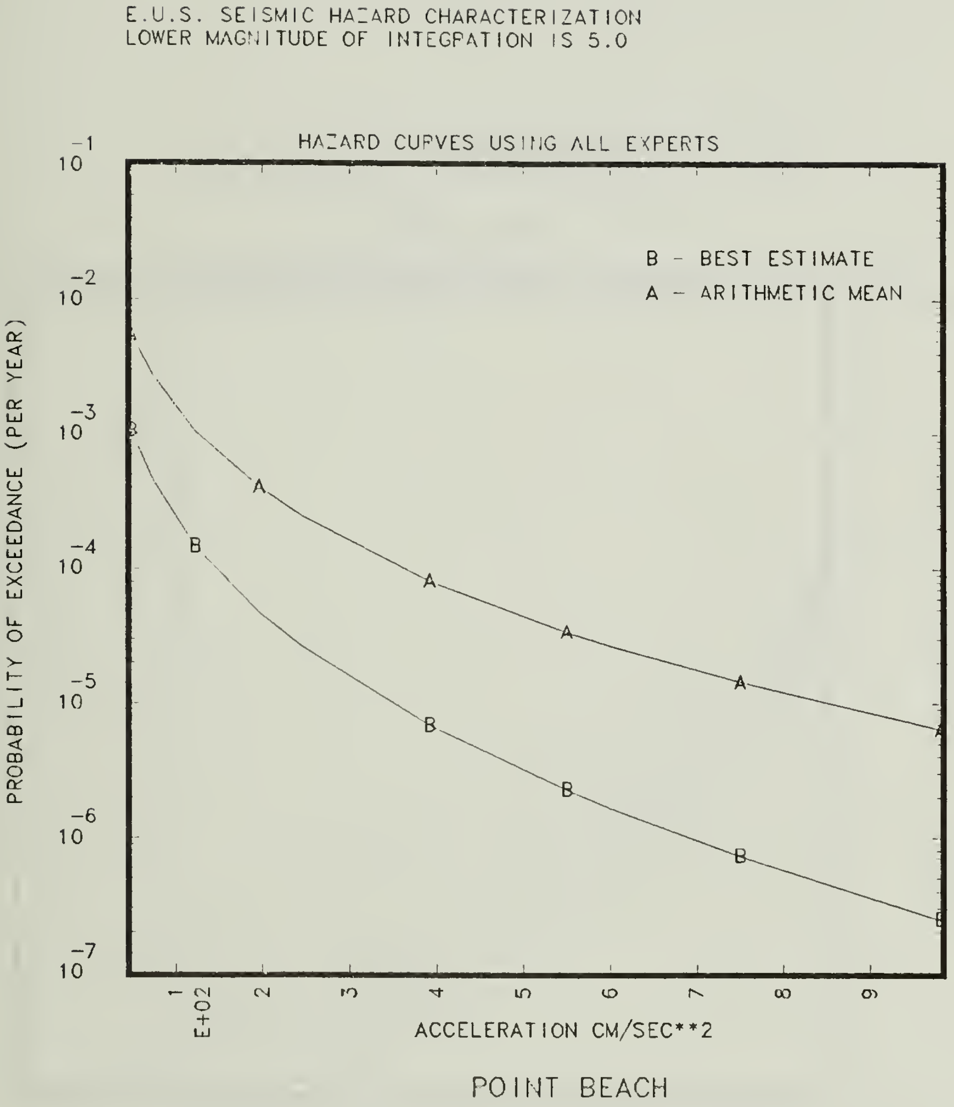


Figure 2.14.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Point Beach site.

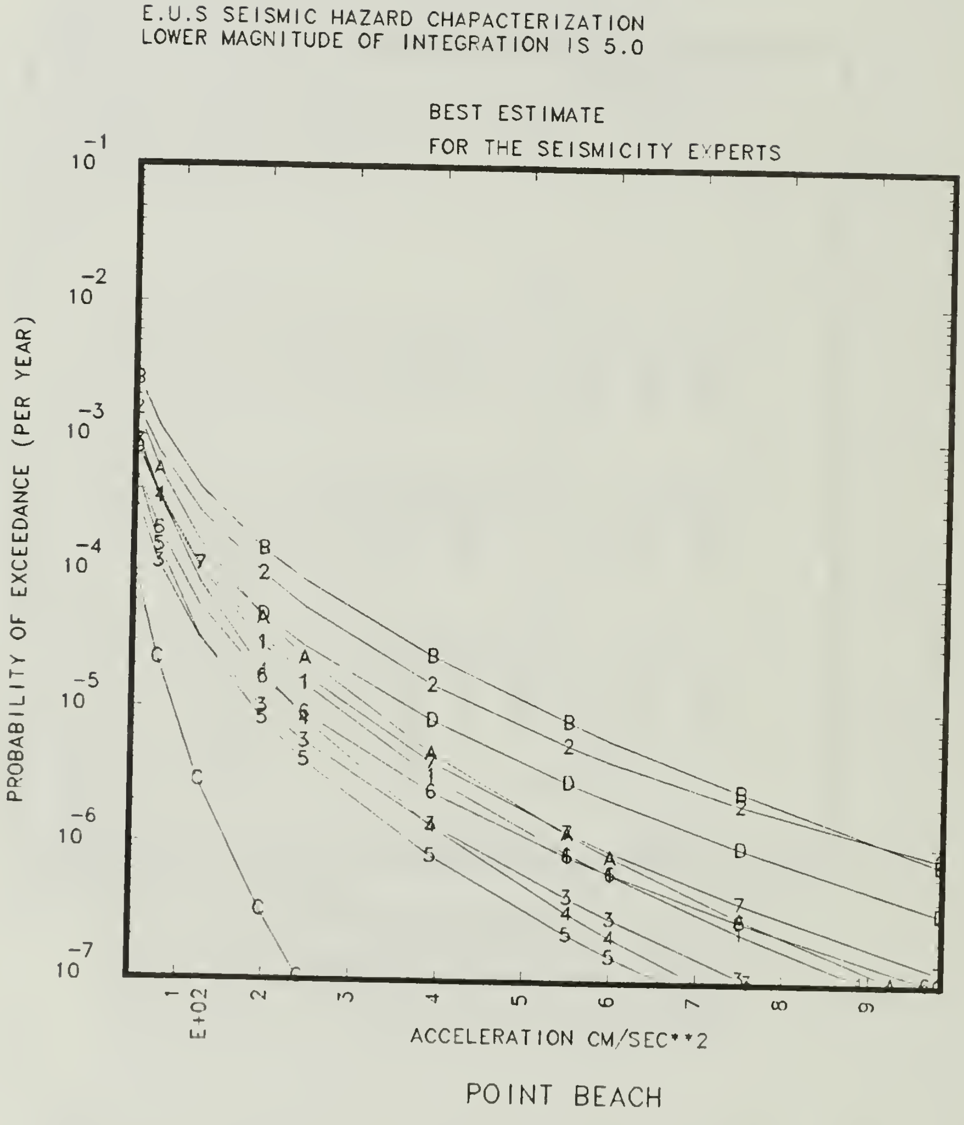


Figure 2.14.2 BEHCs per S-Expert combined over all G-Experts for the Point Beach site. Plot symbols given in Table 2.0.

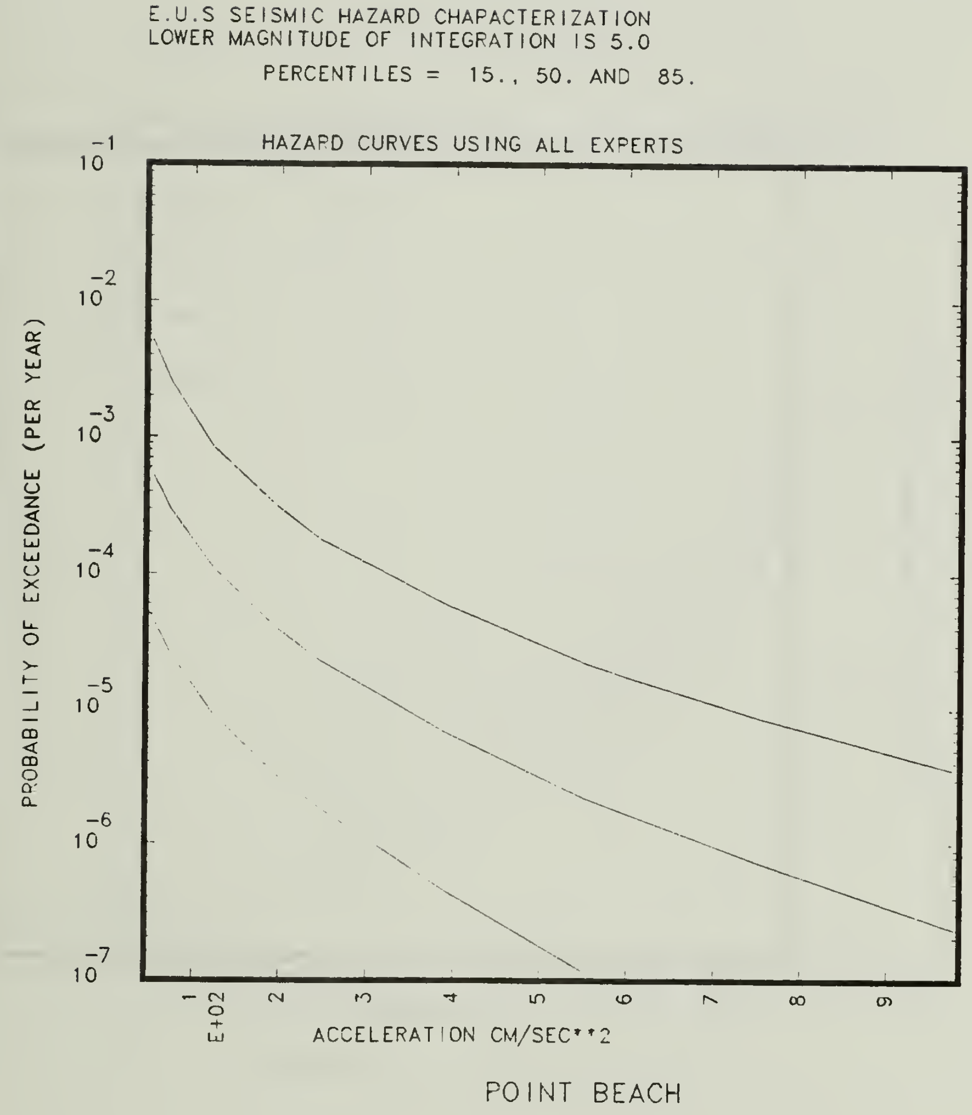


Figure 2.14.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Point Beach site.

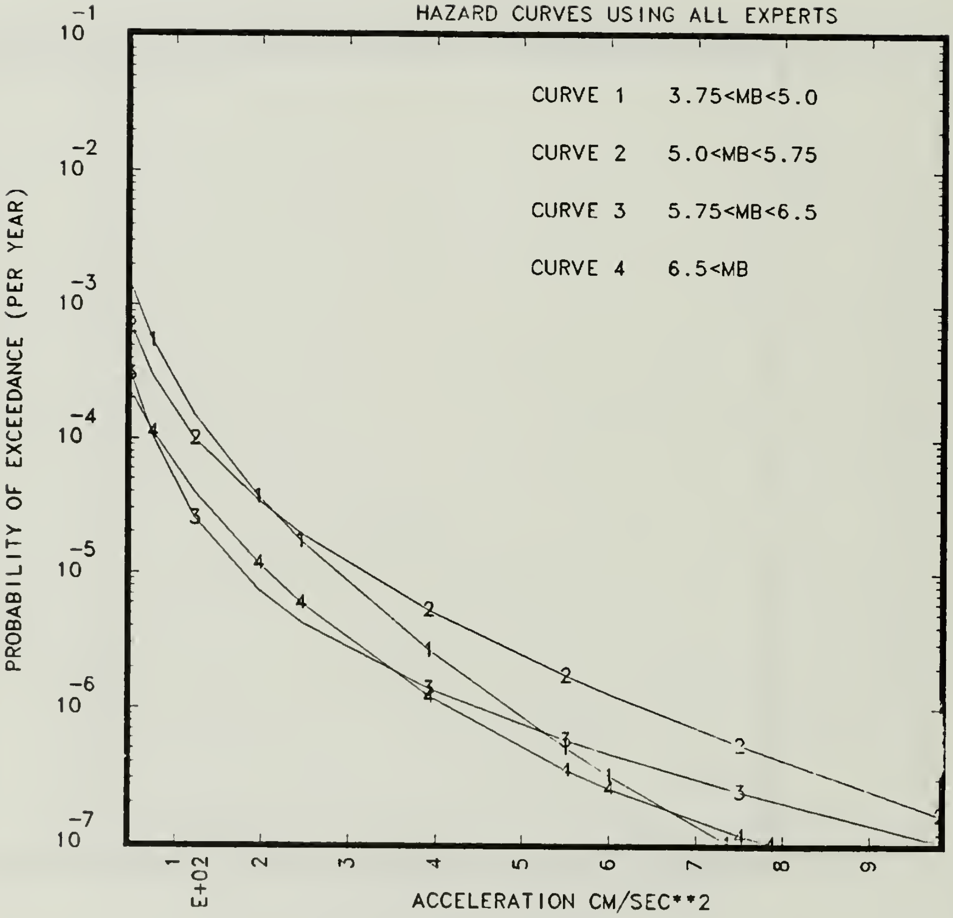


Figure 2.14.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Point Beach site.

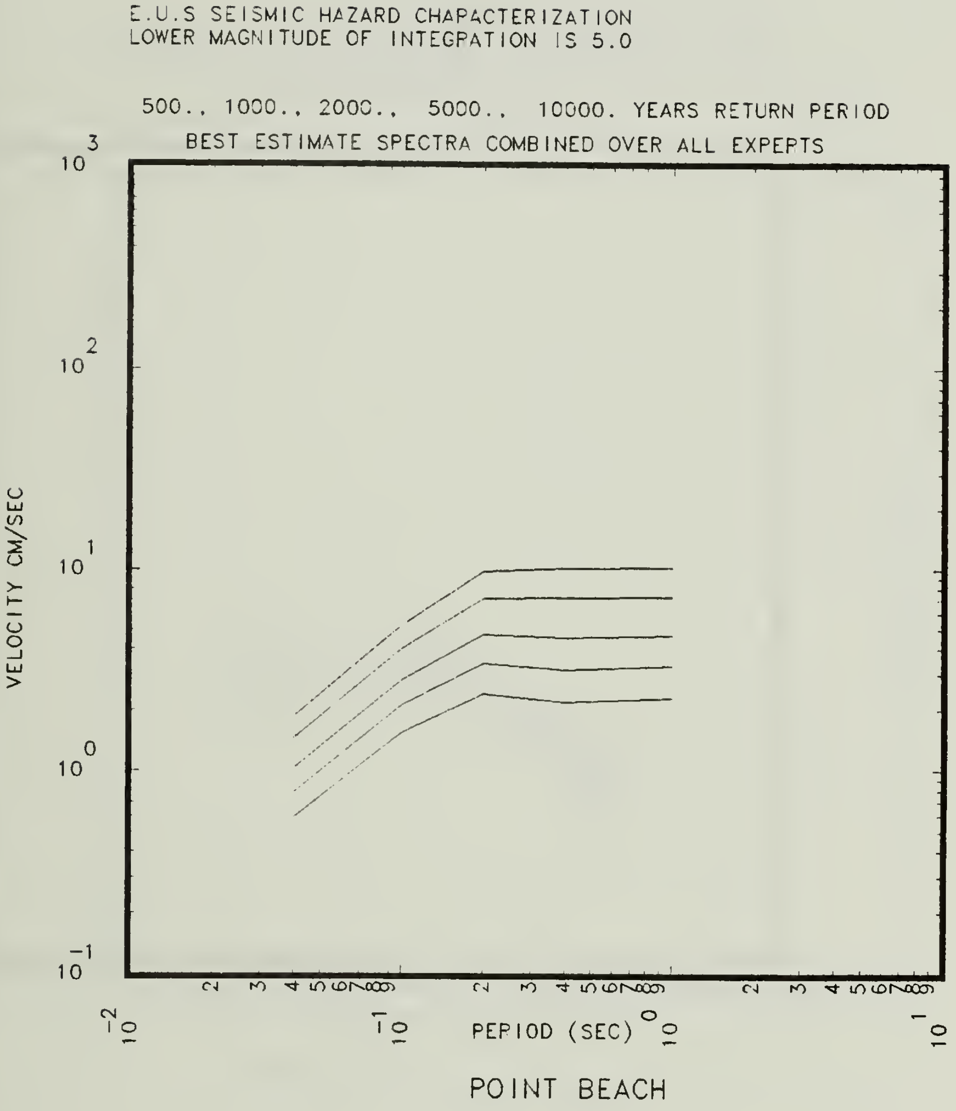


Figure 2.14.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Point Beach site.

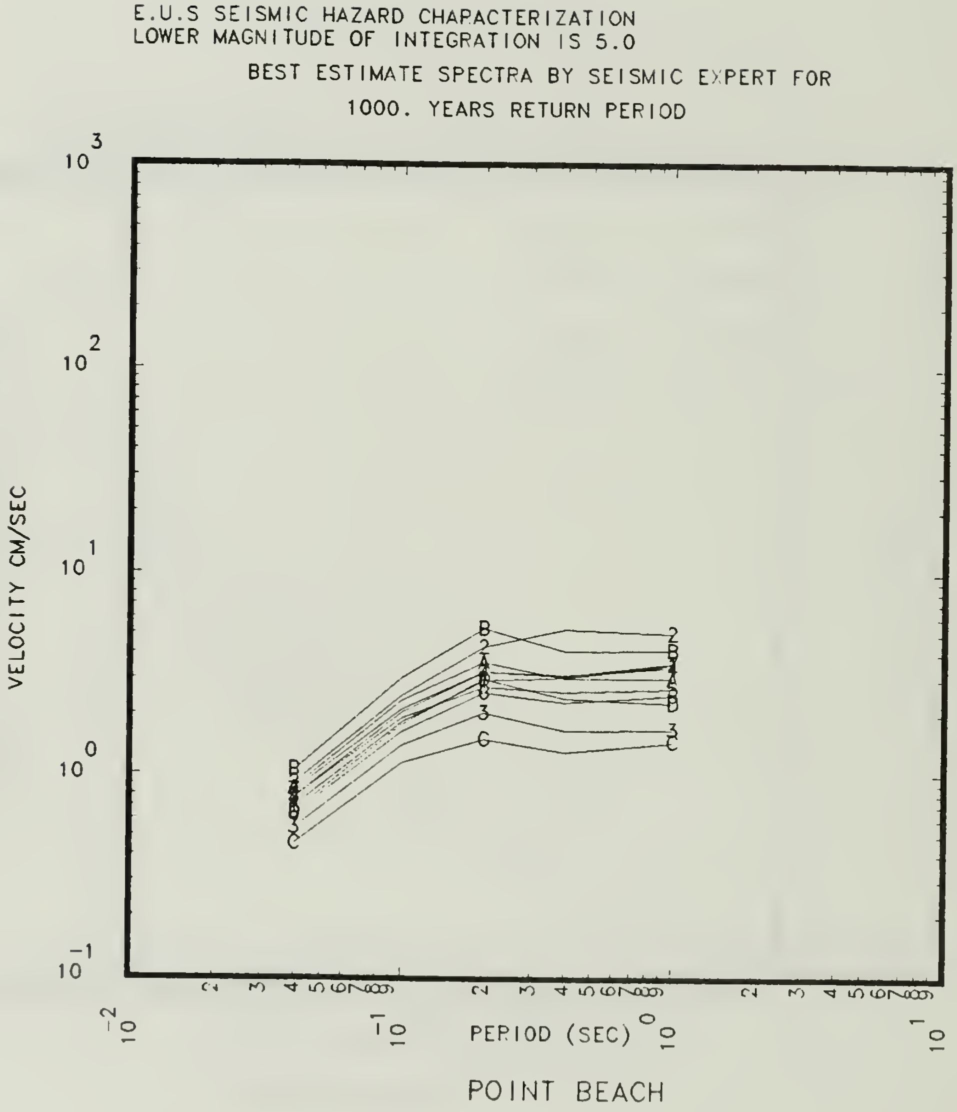


Figure 2.14.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Point Beach site. Plot symbols are given in Table 2.0.

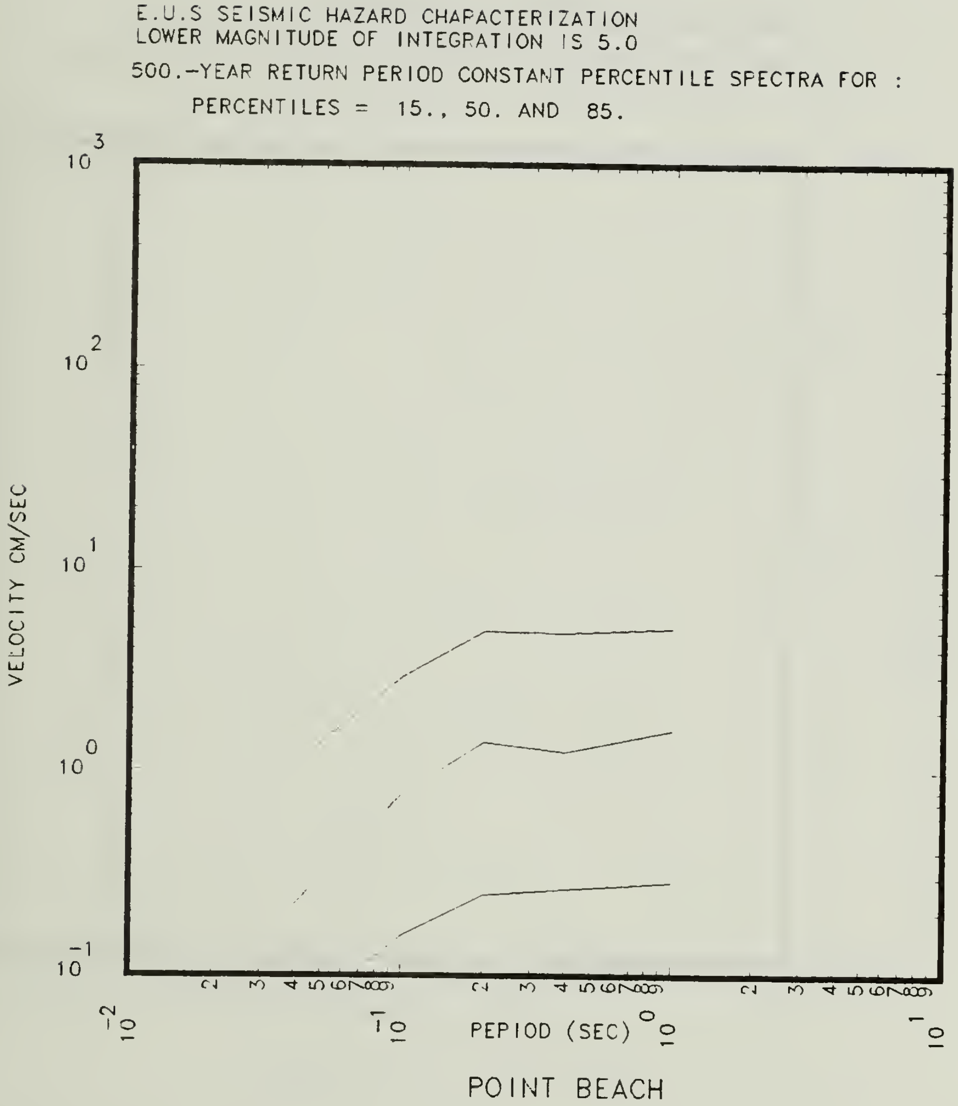


Figure 2.14.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Point Beach site.

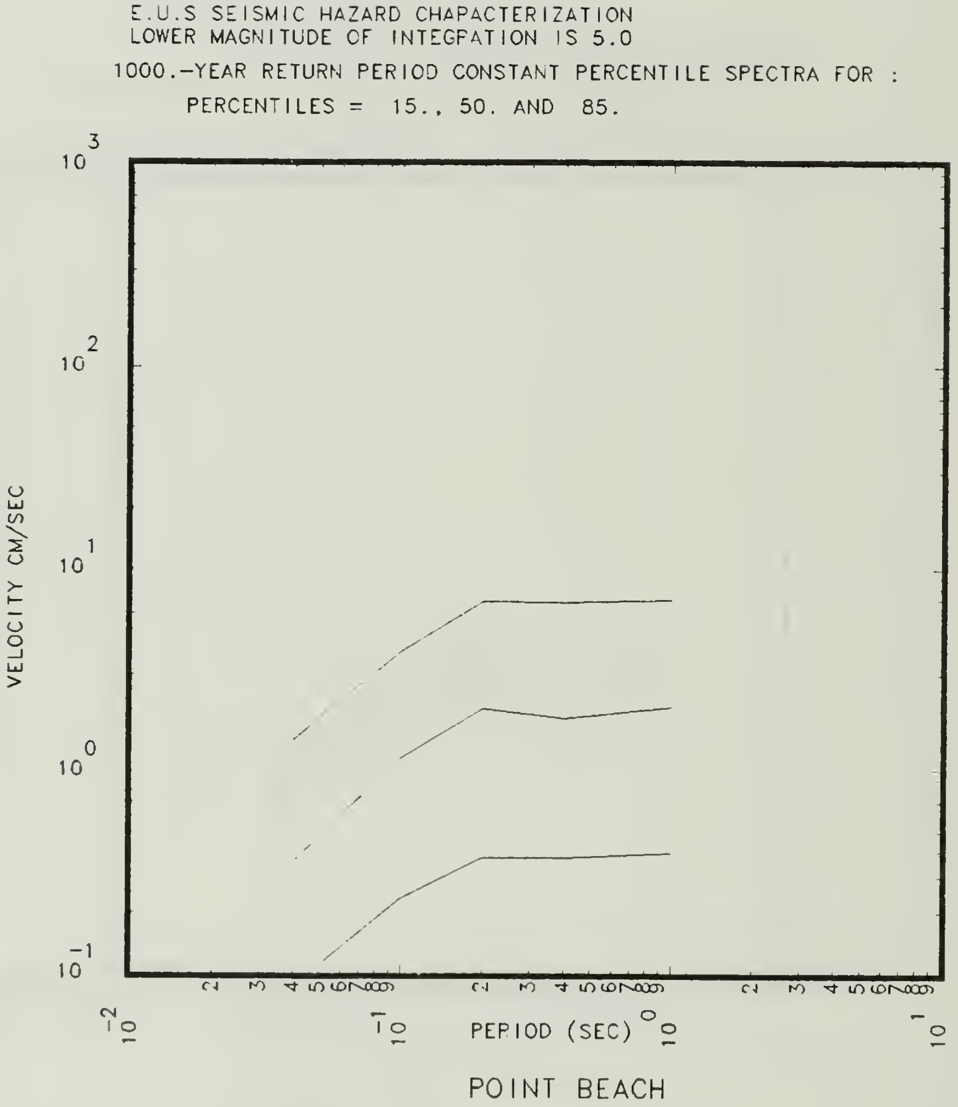


Figure 2.14.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Point Beach site.

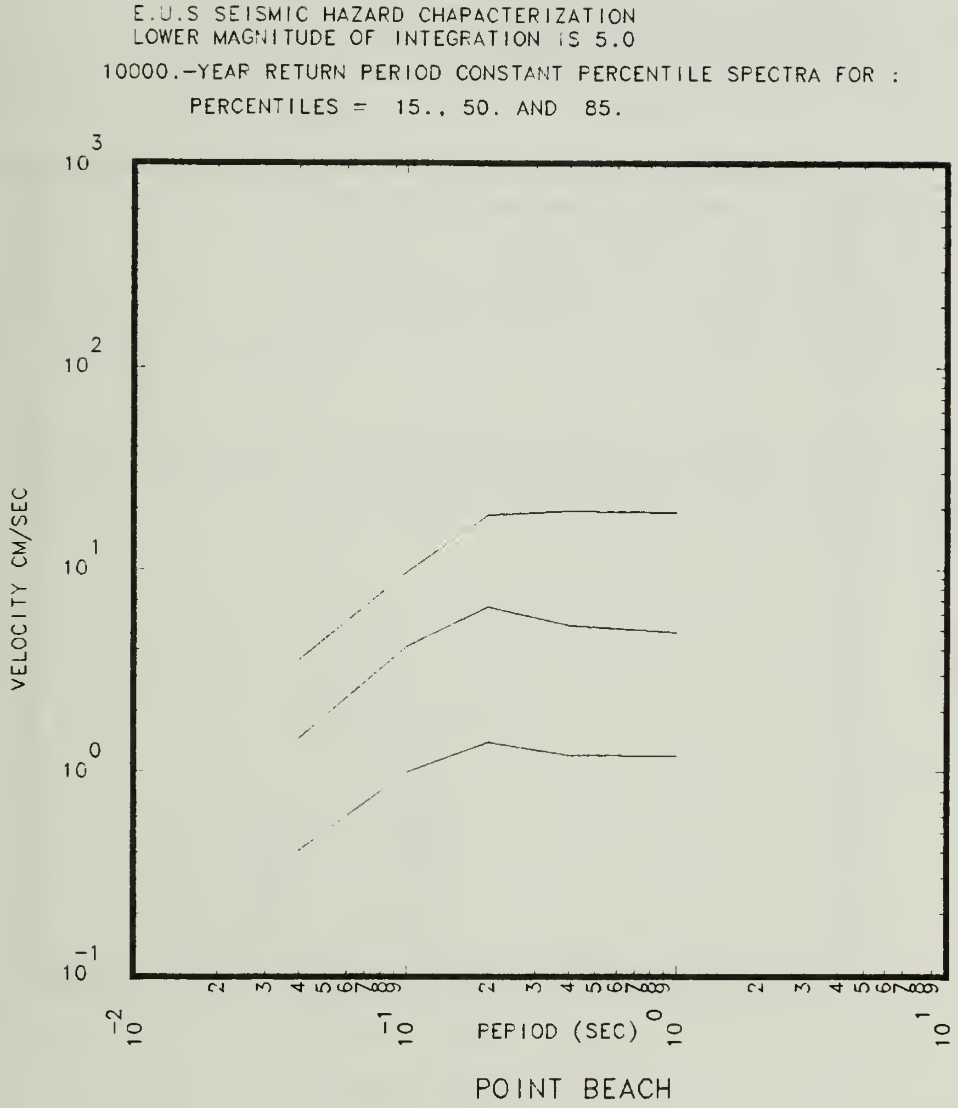


Figure 2.14.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Point Beach site.

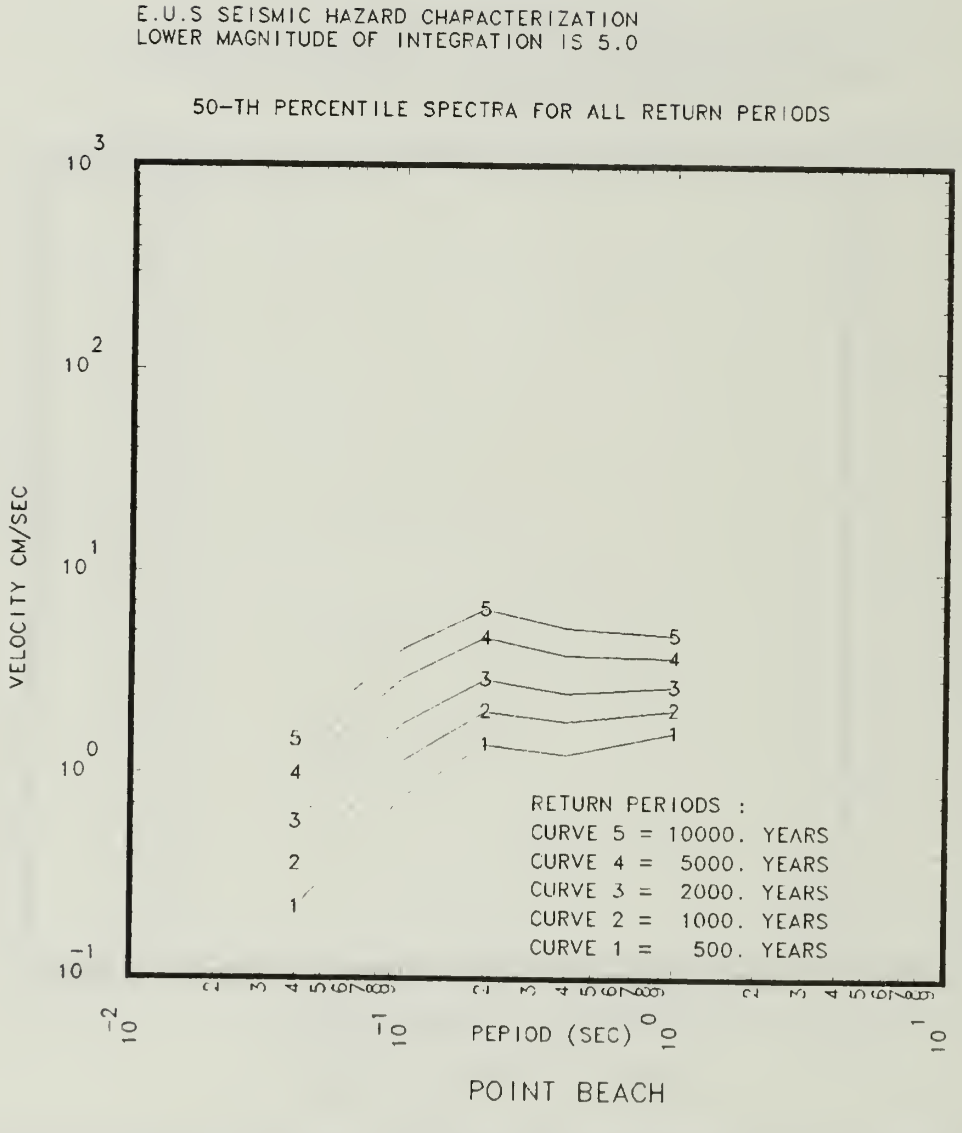


Figure 2.14.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Point Beach site.

2.15 QUAD CITIES

The Quad Cities site is a rock site and it is represented by the symbol "F" in Fig. 1.1. Table 2.15.1 and Figs. 2.15.1 through 2.15.10 give the basic results for the Quad Cities site.

From Table 2.15.1 we see that for S-Experts 2, 4, 5, 7 and 12 the distant New Madrid zones contribute most to the BEHC for PGA and for S-Expert 1 the New Madrid region also contributes significantly. For these S-Experts, as would be expected based on the discussions given in Section 2.3, the spread between G-Expert 5's BEHC and the other G-Experts' BEHCs per S-Experts 1, 2, 4, 5, 7 and 12 is large and similar to the spread shown in Fig. 2.3.12. For S-Experts 3, 6, 10, 11 and 13 the host zone contributes most to the BEHC for PGA. For these S-Experts the spread between the G-Experts' BEHCs is similar to that shown in Fig. 2.3.11.

The spread between the G-Experts' BEHCs leads, as typical for rock sites in region 3, to a relatively wide spread between the AMHC, the BEHC, and the median CPHC of Fig. 2.15.3. There is a relatively wide spread between the S-Experts' BEHCs, but as can be seen by comparing Fig. 2.15.2 to Fig. 2.3.2 that the spread is less at the Quad Cities site than for the Braidwood. The reason for this difference is that the Quad Cities site generally falls into the unzoned CZ for most S-Experts.

We see from Fig. 2.15.4 that large earthquakes contribute most to the BEHC for PGA at the Quad Cities site. We also see from Fig. 2.15.4 that there would be little increase in the BEHC for PGA if earthquakes in the range 3.75 to 5.0 were included.

TABLE 2.15.1

MOST IMPORTANT ZONES PER S-EXPERT
FOR QUAD CITIES

SITE SOIL CATEGORY ROCK

S-XPT NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 15	ZONE ID:	ZONE 11	ZONE 9	ZONE 10	ZONE 19	ZONE 11	ZONE 9	ZONE 19	ZONE 10
		% CONT.:	39.	31.	18.	9.	48.	32.	11.	7.
2	COMP. ZO	ZONE ID:	ZONE 18	ZONE 21	ZONE 20	COMP. ZON	ZONE 18	COMP. ZON	ZONE 21	ZONE 20
		% CONT.:	68.	14.	10.	7.	86.	8.	6.	0.
3	ZONE 15	ZONE ID:	ZONE 15	ZONE 12	ZONE 13	ZONE 16	ZONE 15	ZONE 13	ZONE 12	COMP. ZON
		% CONT.:	54.	22.	18.	2.	89.	6.	4.	1.
4	ZONE 6	ZONE ID:	ZONE 6	ZONE 4	ZONE 5	ZONE 3	ZONE 6	ZONE 4	ZONE 5	ZONE 3
		% CONT.:	52.	40.	6.	2.	77.	22.	1.	0.
5	COMP. ZO	ZONE ID:	ZONE 15	ZONE 14	COMP. ZON	ZONE 12	ZONE 15	COMP. ZON	ZONE 14	ZONE 4
		% CONT.:	83.	10.	3.	3.	97.	3.	0.	0.
6	ZONE 22	ZONE ID:	ZONE 17	ZONE 22	ZONE 18	ZONE 9	ZONE 22	ZONE 17	ZONE 18	COMP. ZON
		% CONT.:	50.	38.	8.	2.	67.	29.	4.	0.
7	ZONE 2 =	ZONE ID:	ZONE 6	ZONE 5	ZONE 2 =	ZONE 34	ZONE 6	ZONE 2 =	ZONE 34	ZONE 5
		% CONT.:	87.	6.	4.	3.	94.	5.	1.	0.
10	ZONE 19	ZONE ID:	ZONE 19 =	ZONE 12A	ZONE 26A	ZONE 13	ZONE 19 =	ZONE 26A	ZONE 12A	ZONE 10
		% CONT.:	70.	15.	9.	6.	97.	2.	1.	0.
11	CZ = ZON	ZONE ID:	ZONE 10	CZ = ZONE	ZONE 11	ZONE 15	CZ = ZONE	ZONE 10	ZONE 11	ZONE 6
		% CONT.:	49.	43.	8.	1.	67.	32.	2.	0.
12	ZONE 4 =	ZONE ID:	ZONE 15	ZONE 13	ZONE 14	ZONE 7	ZONE 15	ZONE 14	ZONE 13	ZONE 5
		% CONT.:	43.	37.	19.	1.	96.	3.	1.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 5	ZONE 6	ZONE 4	CZ 15	ZONE 5	ZONE 6	ZONE 1
		% CONT.:	54.	37.	7.	1.	84.	16.	0.	0.

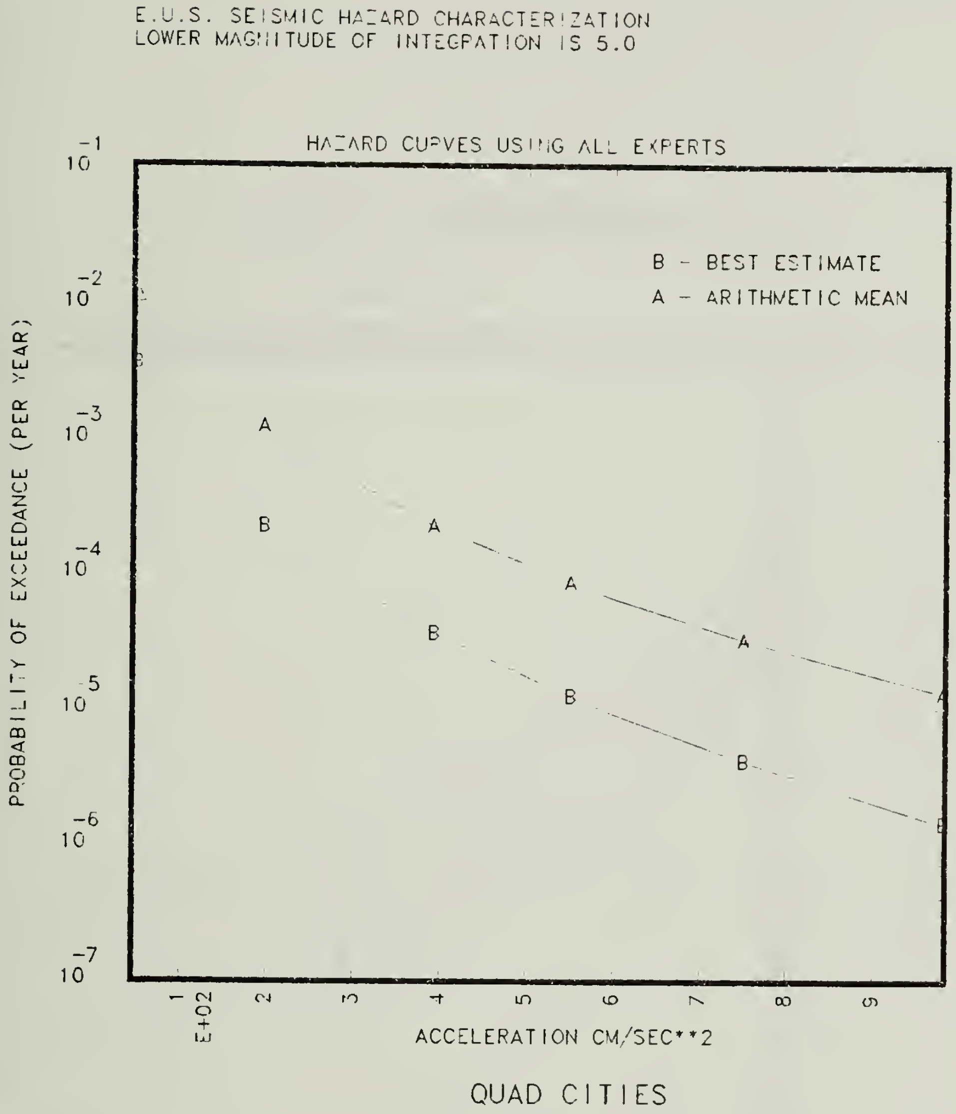


Figure 2.15.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Quad Cities site.

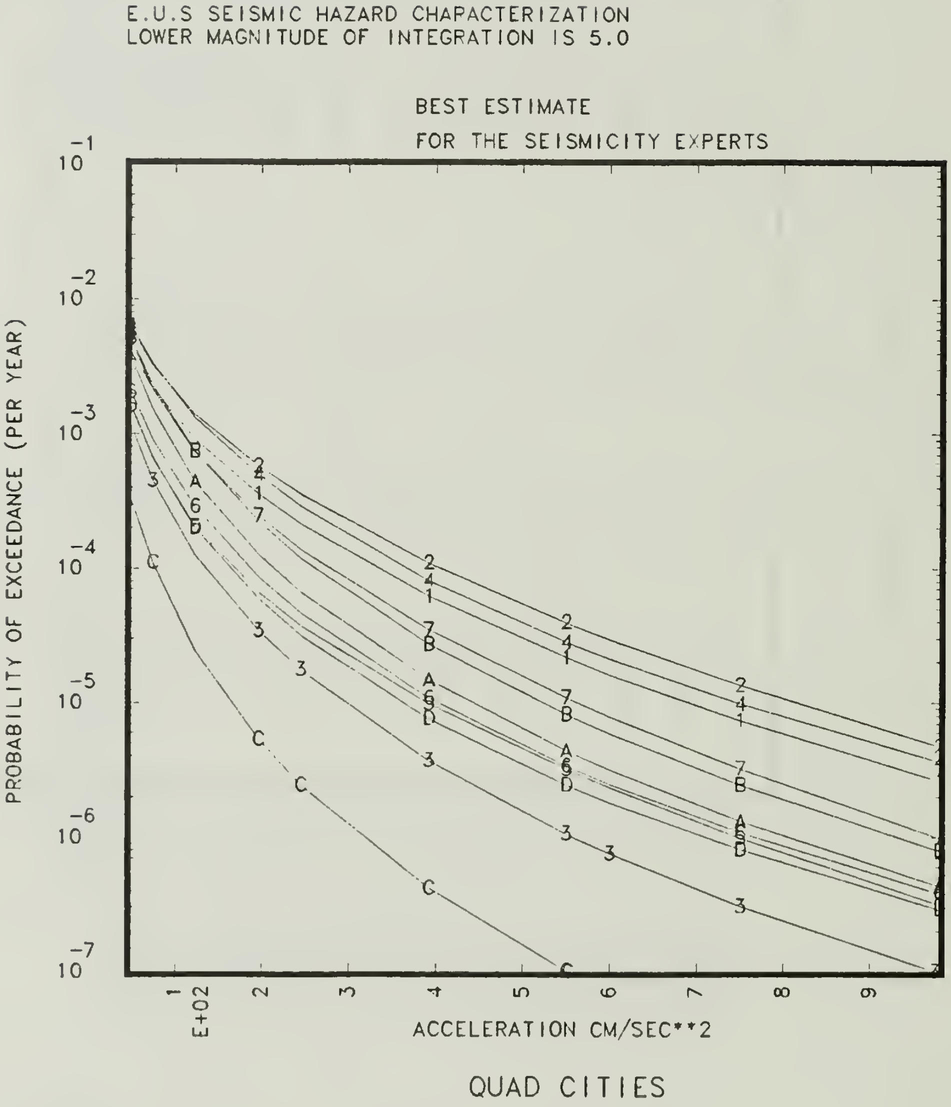


Figure 2.15.2 BEHCs per S-Expert combined over all G-Experts for the Quad Cities site. Plot symbols given in Table 2.0.

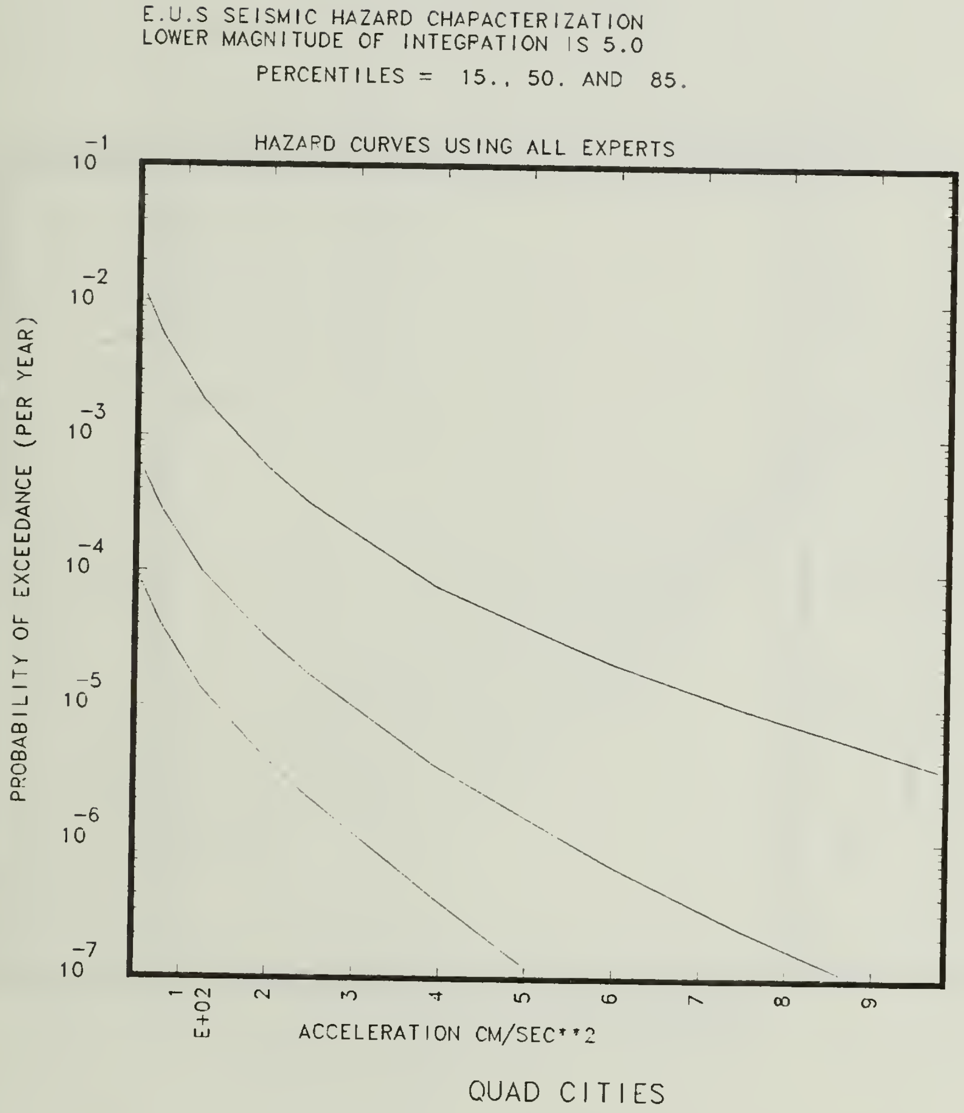
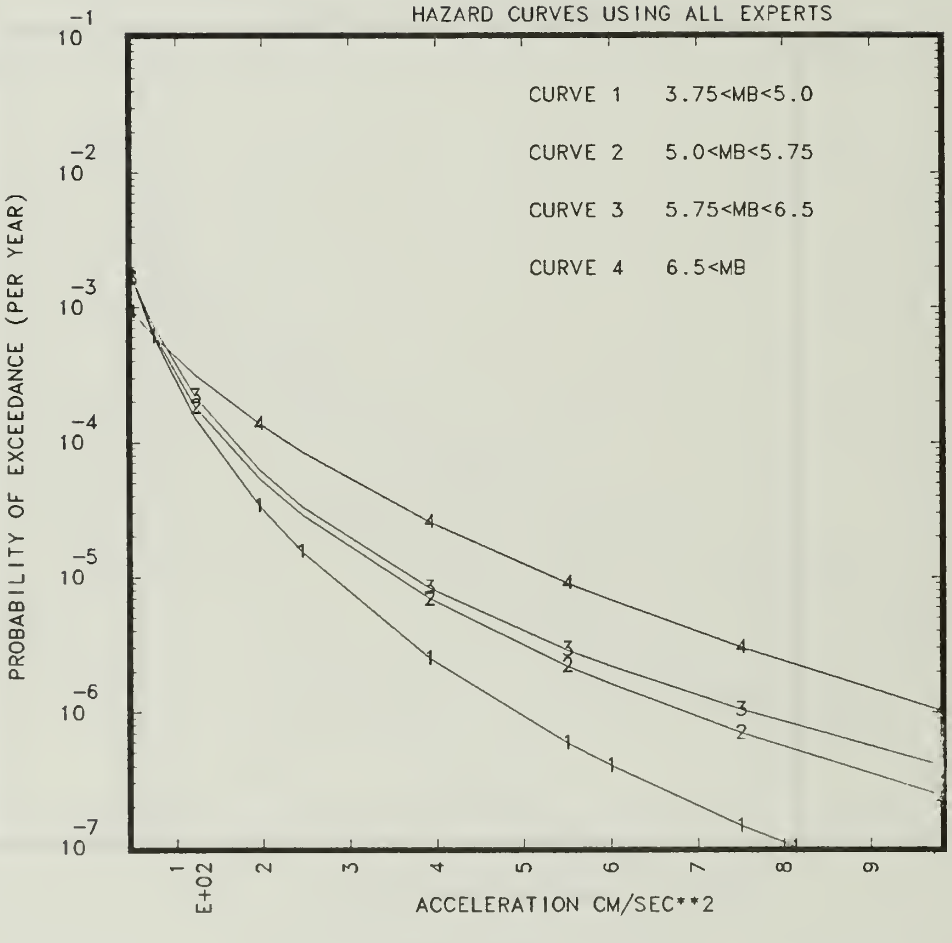


Figure 2.15.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Quad Cities site.



QUAD CITIES

Figure 2.15.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Quad Cities site.

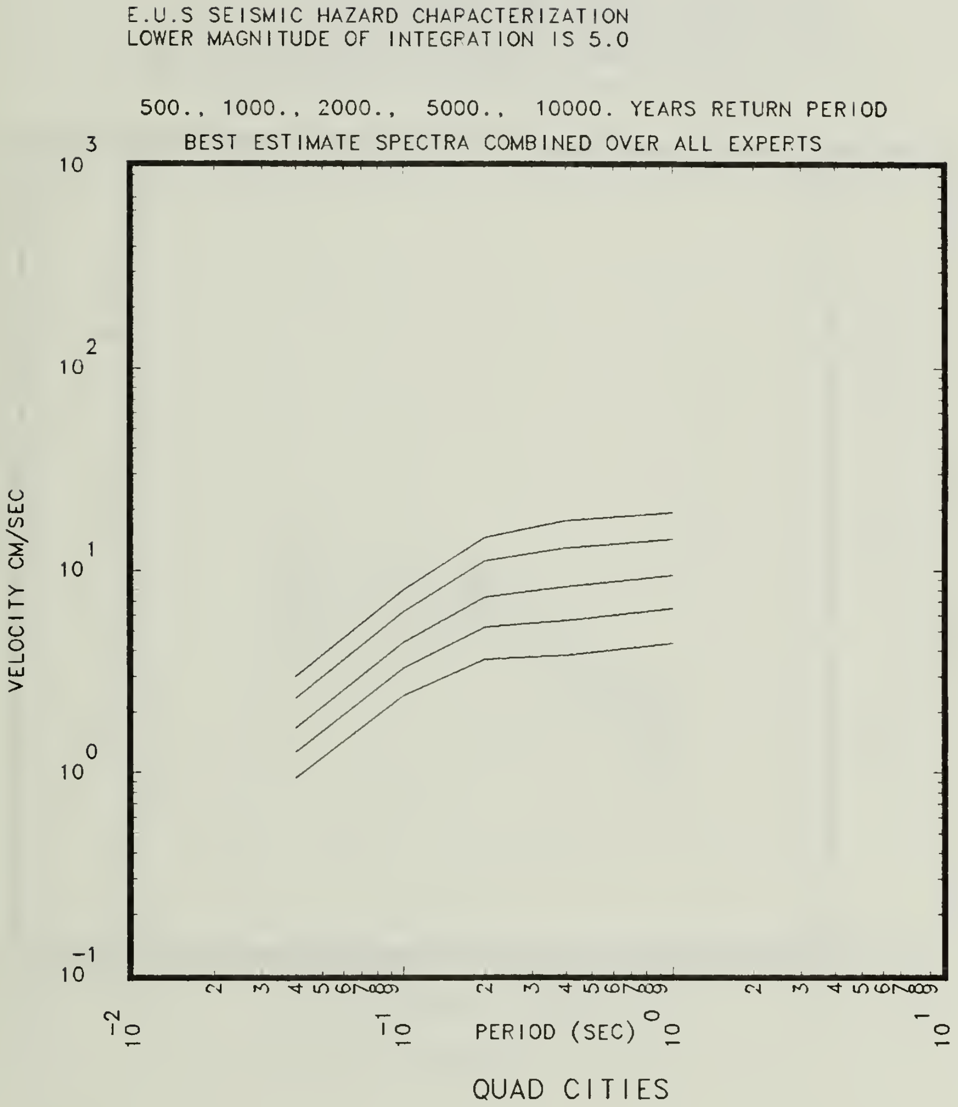


Figure 2.15.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Quad Cities site.

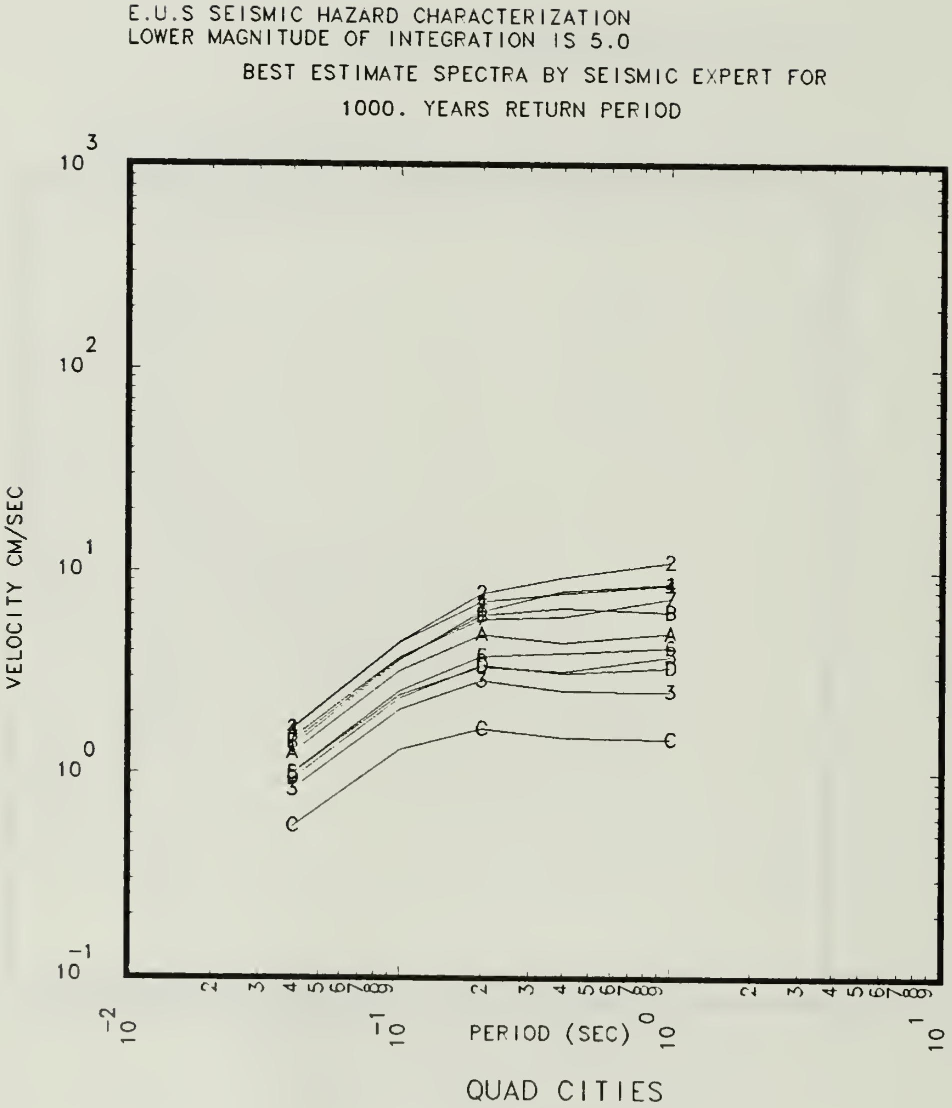


Figure 2.15.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Quad Cities site. Plot symbols are given in Table 2.0.

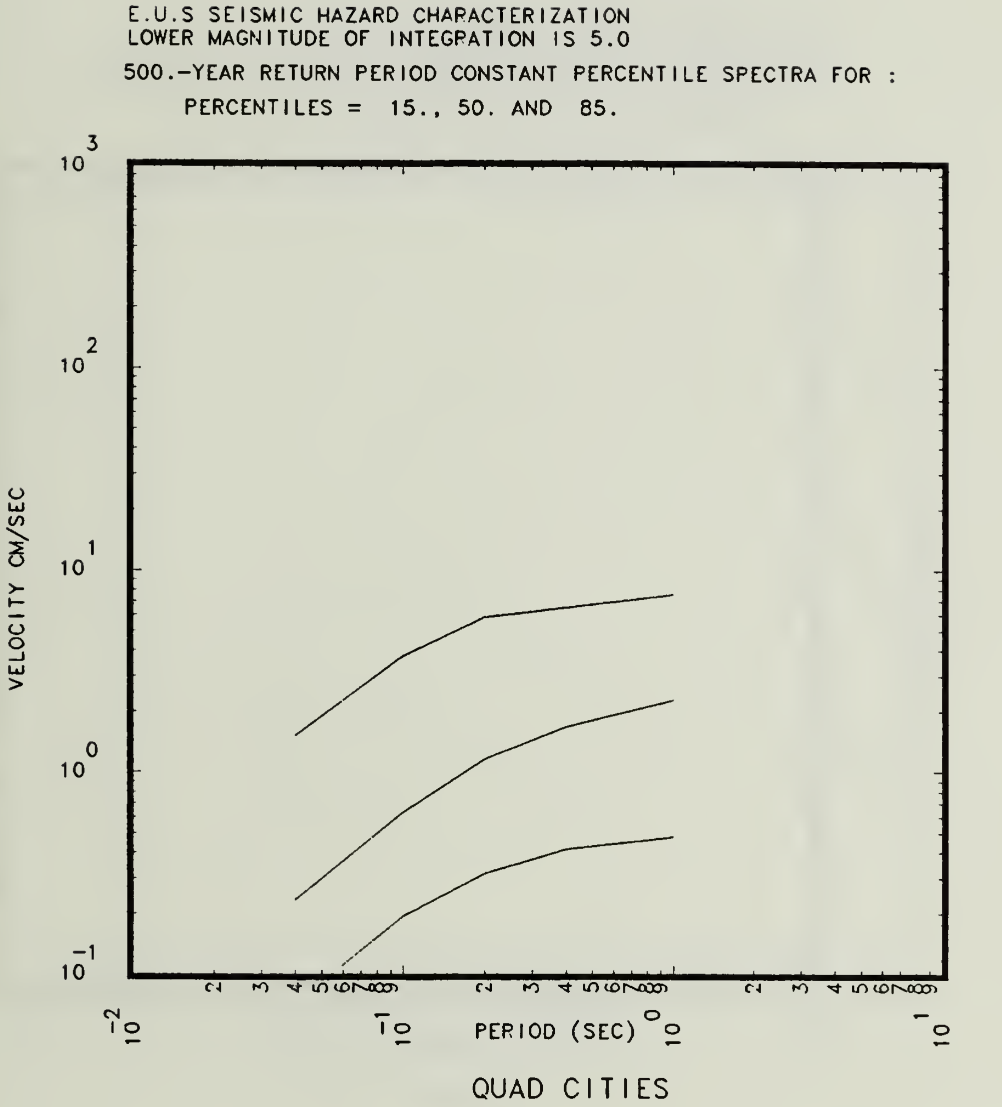


Figure 2.15.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Quad Cities site.

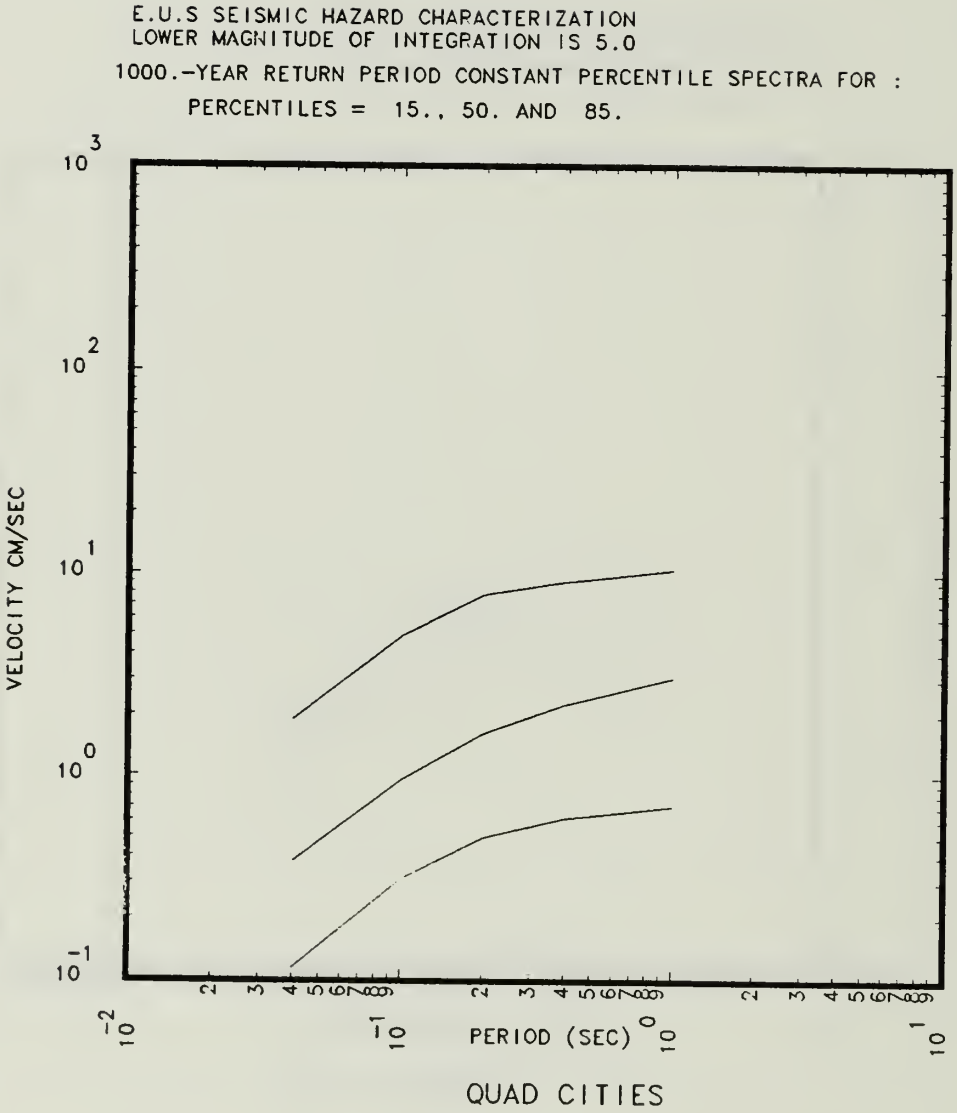


Figure 2.15.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Quad Cities site.

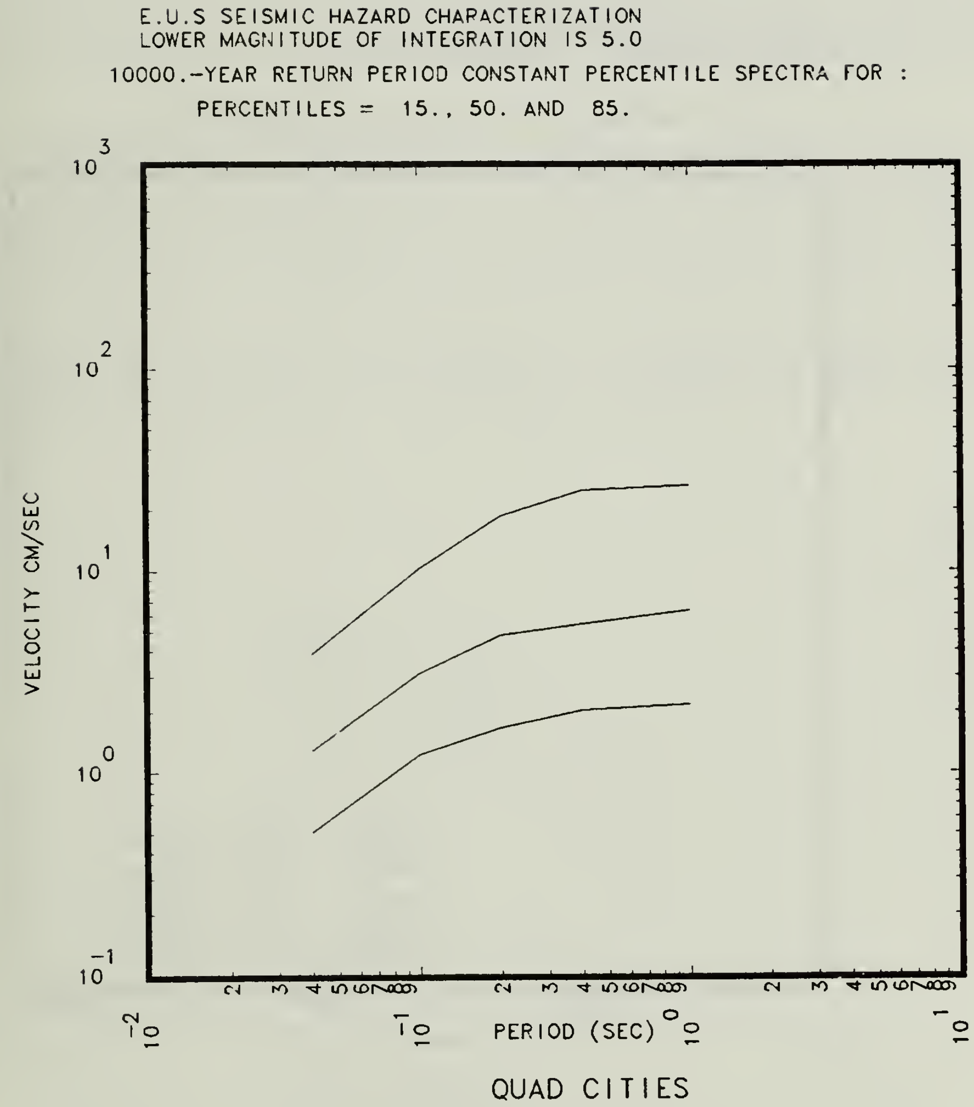


Figure 2.15.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Quad Cities site.

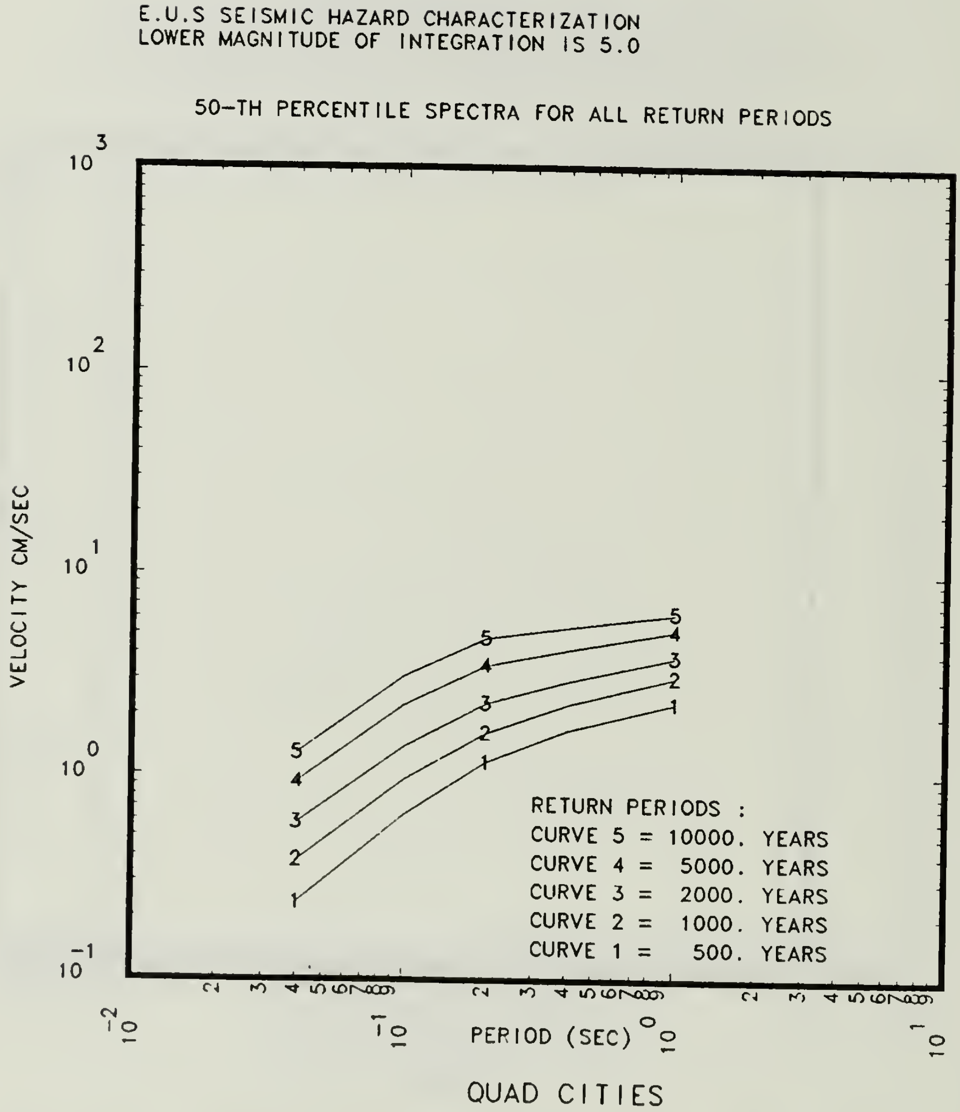


Figure 2.15.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Quad Cities site.

2.16 ZION

The Zion site's soil category is sand-like 2 and it is represented by the symbol "G" in Fig. 1.1. Table 2.16.1 and Figs. 2.16.1 to 2.16.10 give the basic results for the Zion site.

We see from Table 2.16.1 that for S-Experts 1, 2, 4, 5, 7 and 12 that distant New Madrid zones contribute most to the BEHC for PGA. For these S-Experts for the Zion site the spread between the G-Experts' BEHCs per S-Expert is relatively large and similar to the spread shown in Fig. 2.6.11. For S-Experts 3, 6, 10, 11 and 13 the host zone contributes most to the BEHC for PGA. For S-Experts 3, 6, 10, 11 and 13 the spread between the G-Experts' BEHCs per S-Expert is relatively small and similar to the spread shown in Fig. 2.1.12.

We see from Fig. 2.16.2 that there is a wide spread between S-Experts' BEHCs. S-Expert 12 is low, as noted in Section 2.1, because S-Expert 12 assigned an upper magnitude cutoff of 5 to the CZ which contained the site S-Expert 4 is in part high because he has a zone 6 which contains the site, and in part because of the seismicity parameters assigned to zone 6 by S-Expert 4.

We see from Fig. 2.16.4 that earthquakes in the magnitude range of 3.75 to 5 were included but the BEHC for PGA would be increased by about a factor of 2 in probability of exceedance in the 0.05g to 0.4g.

TABLE 2.16.1

MOST IMPORTANT ZONES PER S-EXPERT FOR ZION

SITE SOIL CATEGORY SAND-2

S-XPT NUM.	HOST ZONE		ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA(0.125G)				AT HIGH PGA(0.60G)			
1	ZONE 15	ZONE ID:	ZONE 9	ZONE 19	ZONE 11	ZONE 15	ZONE 9	ZONE 15	ZONE 19	ZONE 11
		% CONT.:	35.	22.	20.	12.	42.	31.	16.	9.
2	COMP. ZO	ZONE ID:	ZONE 18	COMP. ZON	ZONE 21	ZONE 20	ZONE 18	COMP. ZON	ZONE 21	ZONE 20
		% CONT.:	62.	18.	14.	5.	53.	45.	2.	0.
3	ZONE 15	ZONE ID:	ZONE 15	ZONE 13	ZONE 12	ZONE 11	ZONE 15	COMP. ZON	ZONE 13	ZONE 12
		% CONT.:	90.	4.	3.	2.	99.	0.	0.	0.
4	ZONE 6	ZONE ID:	ZONE 6	ZONE 4	ZONE 5	ZONE 13	ZONE 6	ZONE 4	COMP. ZON	ZONE 5
		% CONT.:	83.	15.	1.	0.	98.	2.	0.	0.
5	COMP. ZO	ZONE ID:	ZONE 15	ZONE 12	COMP. ZON	ZONE 14	ZONE 15	COMP. ZON	ZONE 4	ZONE 6
		% CONT.:	71.	13.	11.	3.	76.	24.	0.	0.
6	ZONE 22	ZONE ID:	ZONE 22	ZONE 17	ZONE 9	ZONE 18	ZONE 22	ZONE 17	ZONE 18	ZONE 9
		% CONT.:	75.	18.	3.	3.	97.	3.	0.	0.
7	ZONE 2 =	ZONE ID:	ZONE 6	ZONE 34	ZONE 2 =	ZONE 5	ZONE 6	ZONE 2 =	ZONE 34	ZONE 3
		% CONT.:	64.	24.	8.	3.	58.	29.	13.	0.
10	ZONE 26A	ZONE ID:	ZONE 26A	ZONE 27	ZONE 19 =	ZONE 12A	ZONE 26A	ZONE 19 =	ZONE 27	ZONE 5
		% CONT.:	92.	3.	3.	2.	98.	2.	0.	0.
11	CZ = ZON	ZONE ID:	CZ = ZONE	ZONE 10	ZONE 11	ZONE 9	CZ = ZONE	ZONE 10	ZONE 11	ZONE 2
		% CONT.:	82.	15.	3.	0.	99.	1.	0.	0.
12	ZONE 4 =	ZONE ID:	ZONE 15	ZONE 13	ZONE 14	ZONE 31A	ZONE 15	ZONE 5	ZONE 6	ZONE 7
		% CONT.:	58.	18.	15.	5.	100.	0.	0.	0.
13	CZ 15	ZONE ID:	CZ 15	ZONE 5	ZONE 6	ZONE 4	CZ 15	ZONE 5	ZONE 1	ZONE 3
		% CONT.:	87.	12.	1.	0.	99.	1.	0.	0.

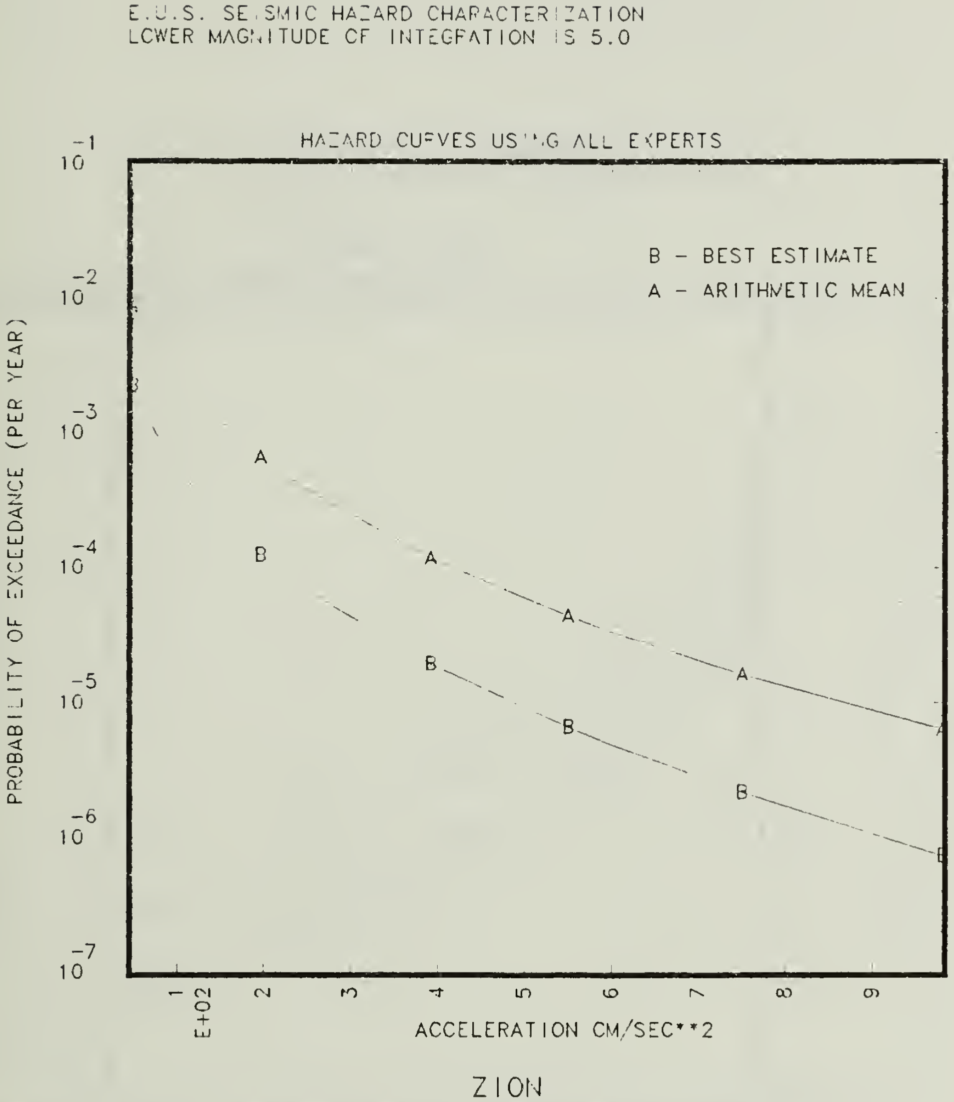


Figure 2.16.1 Comparison of the BEHC and AMHC aggregated over all S and G-Experts for the Zion site.

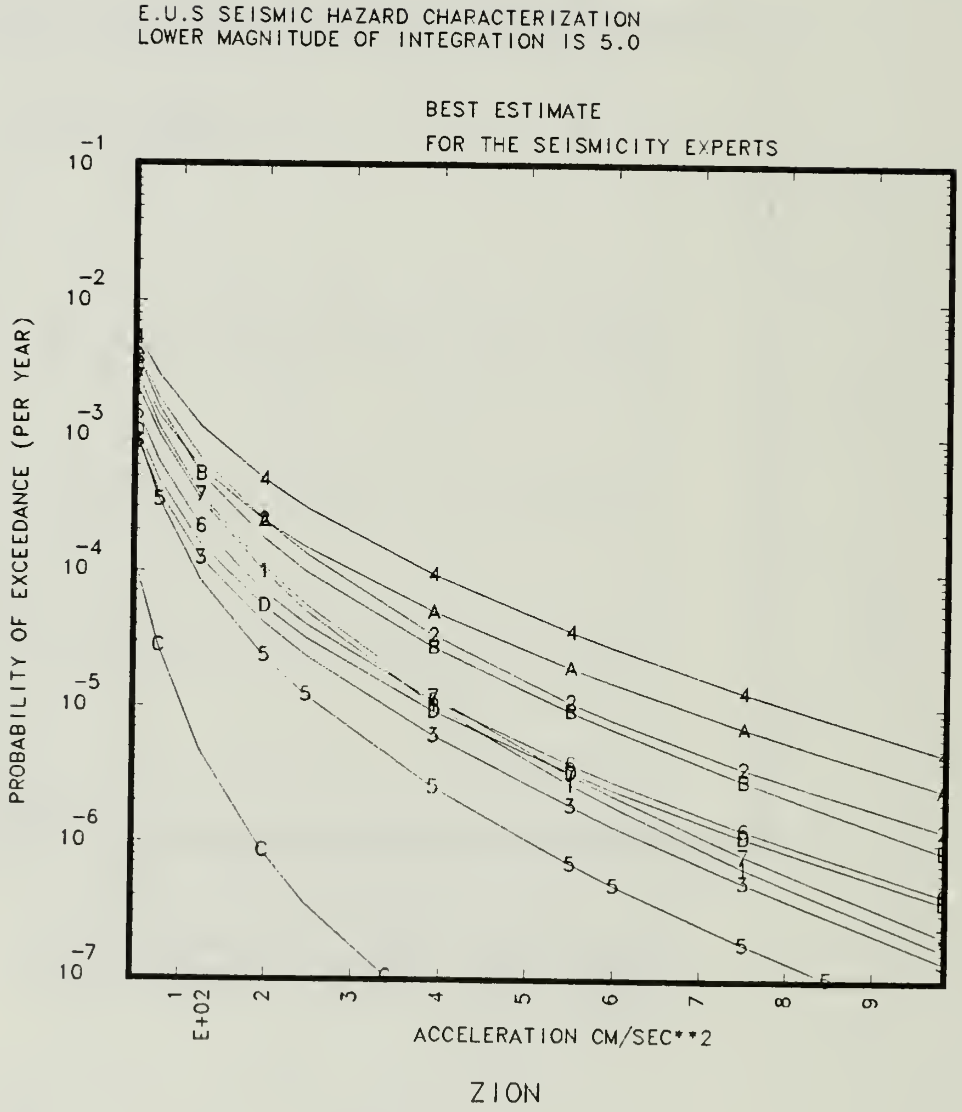


Figure 2.16.2 BEHCs per S-Expert combined over all G-Experts for the Zion site. Plot symbols given in Table 2.0.

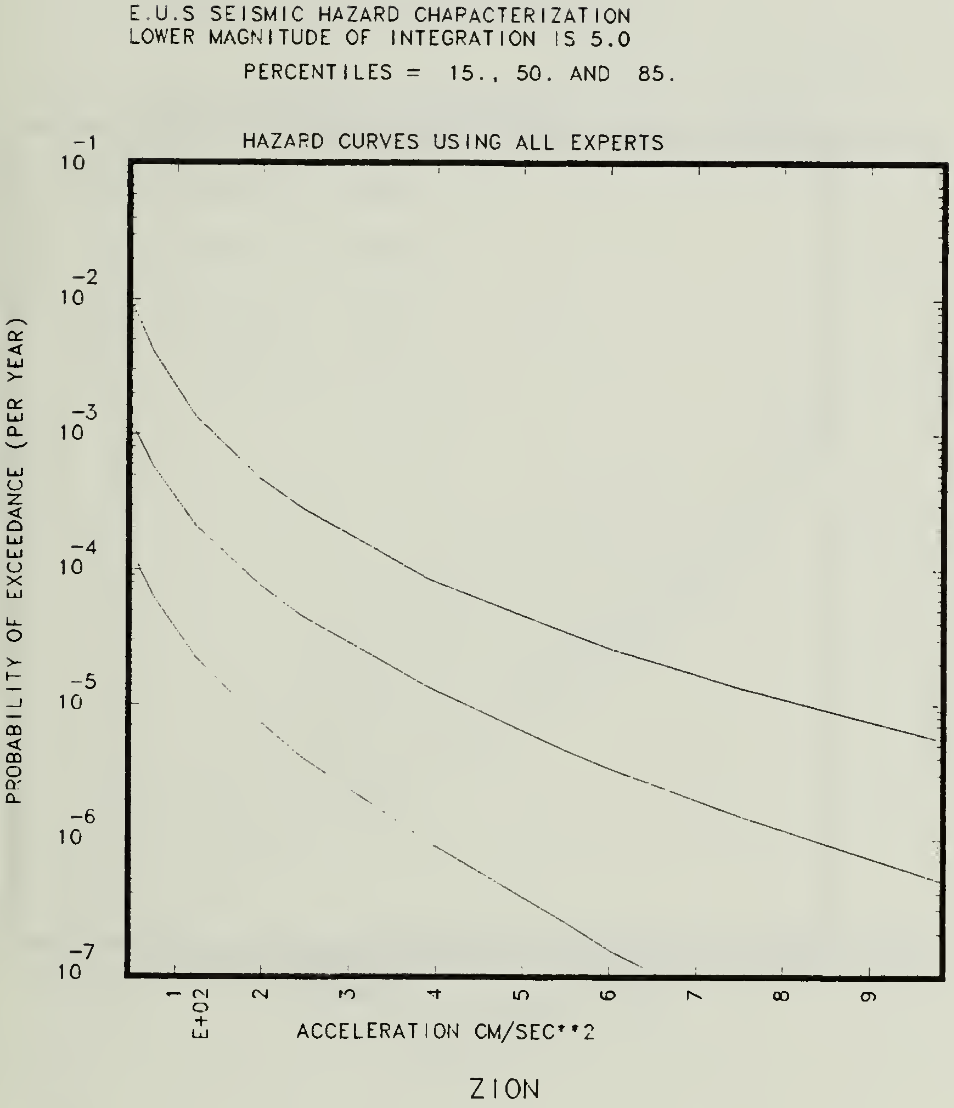


Figure 2.16.3 CPHCs for the 15th, 50th and 85th percentiles based on all S and G-Experts' input for the Zion site.

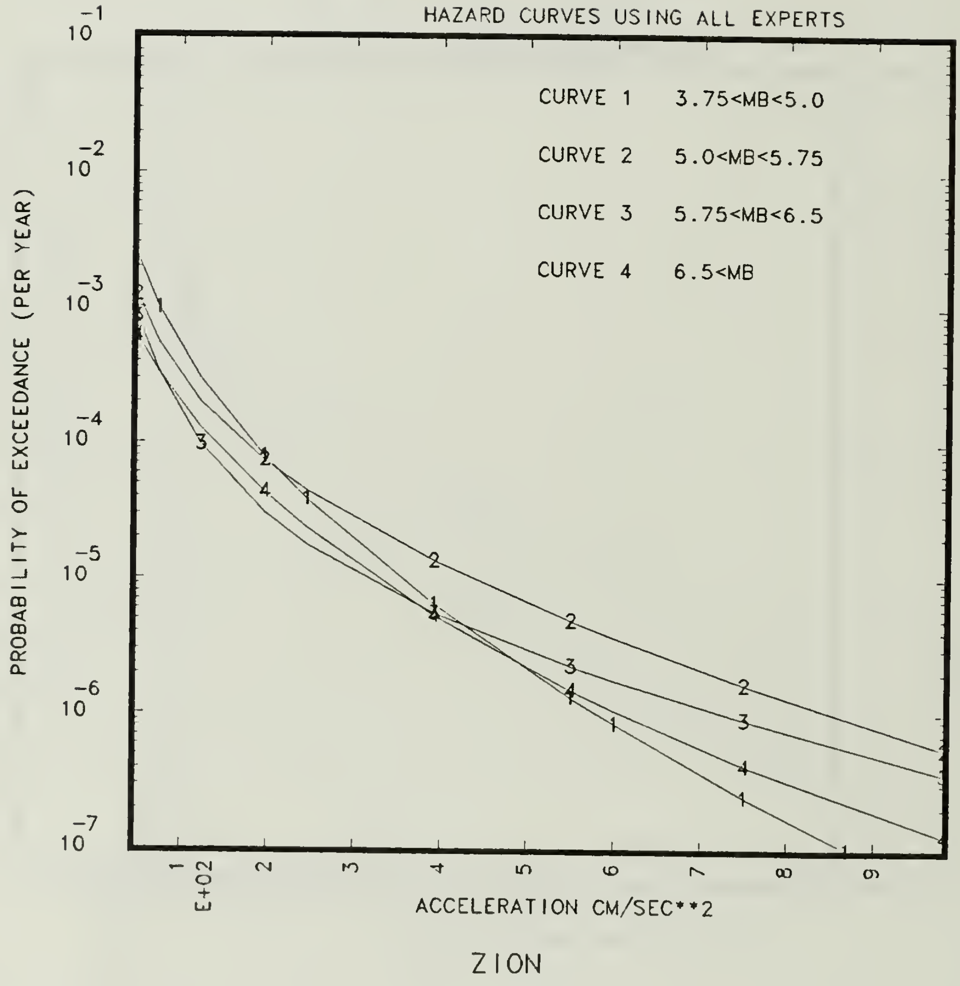


Figure 2.16.4 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated magnitude range for the Zion site.

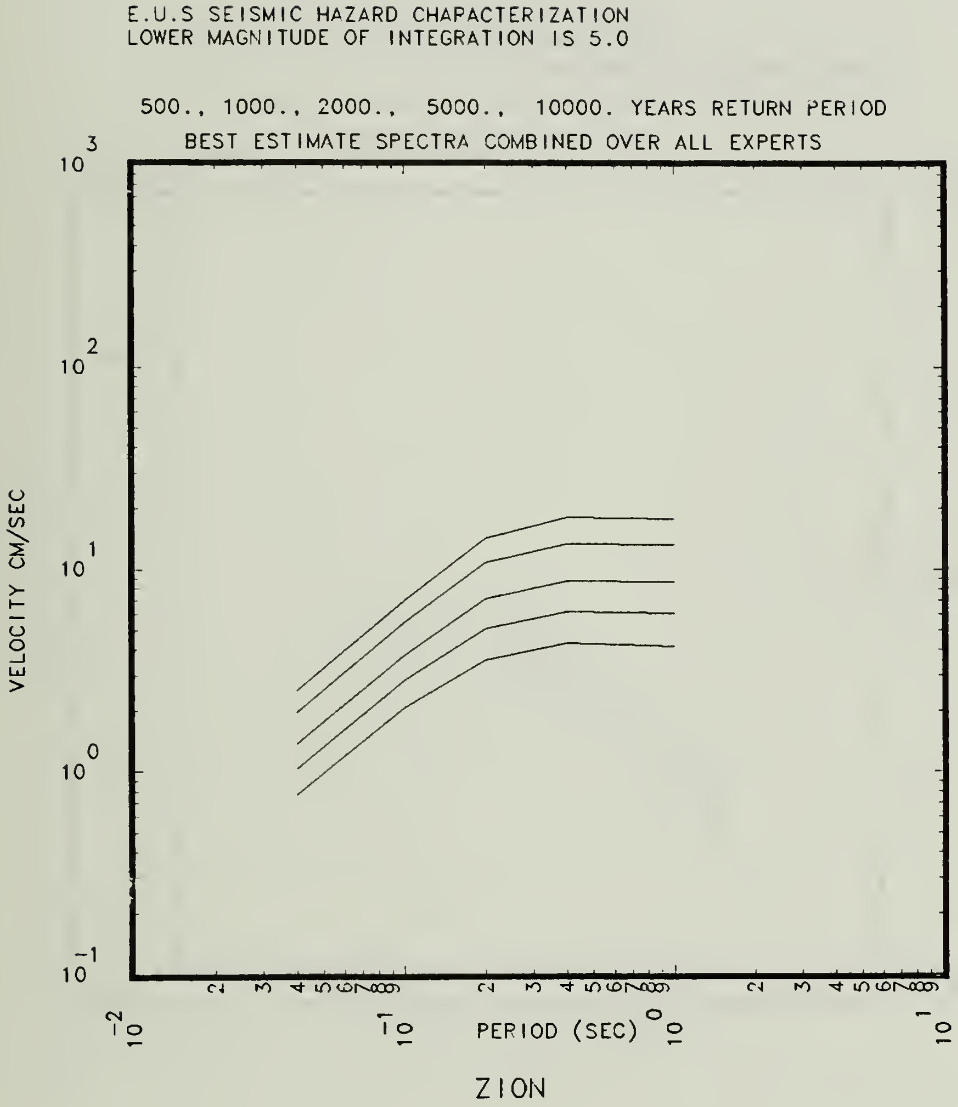


Figure 2.16.5 BEUHS for return periods of 500, 1000, 2000, 5000 and 10000 years aggregated over all S and G-Experts for the Zion site.

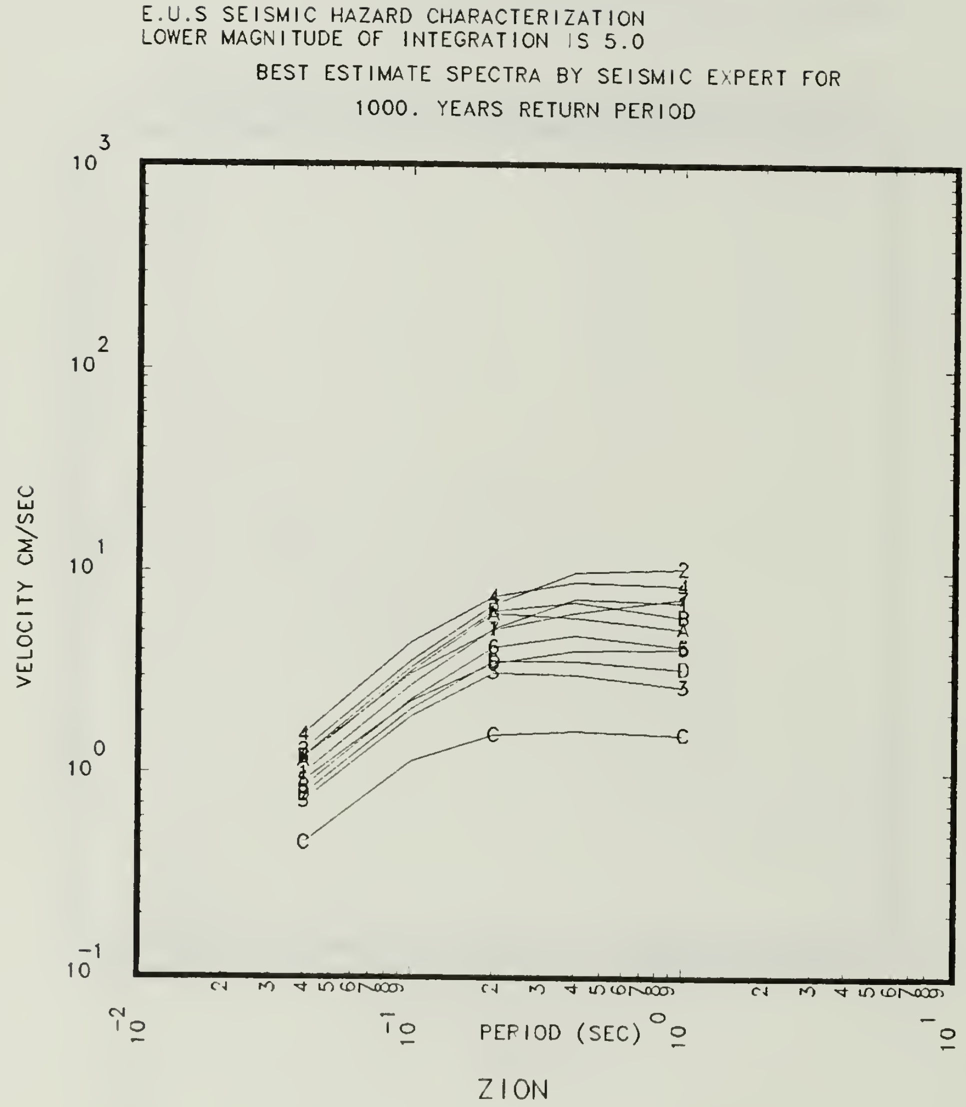


Figure 2.16.6 The 1000 year return period BEUHS per S-Expert aggregated over all G-Experts for the Zion site. Plot symbols are given in Table 2.0.

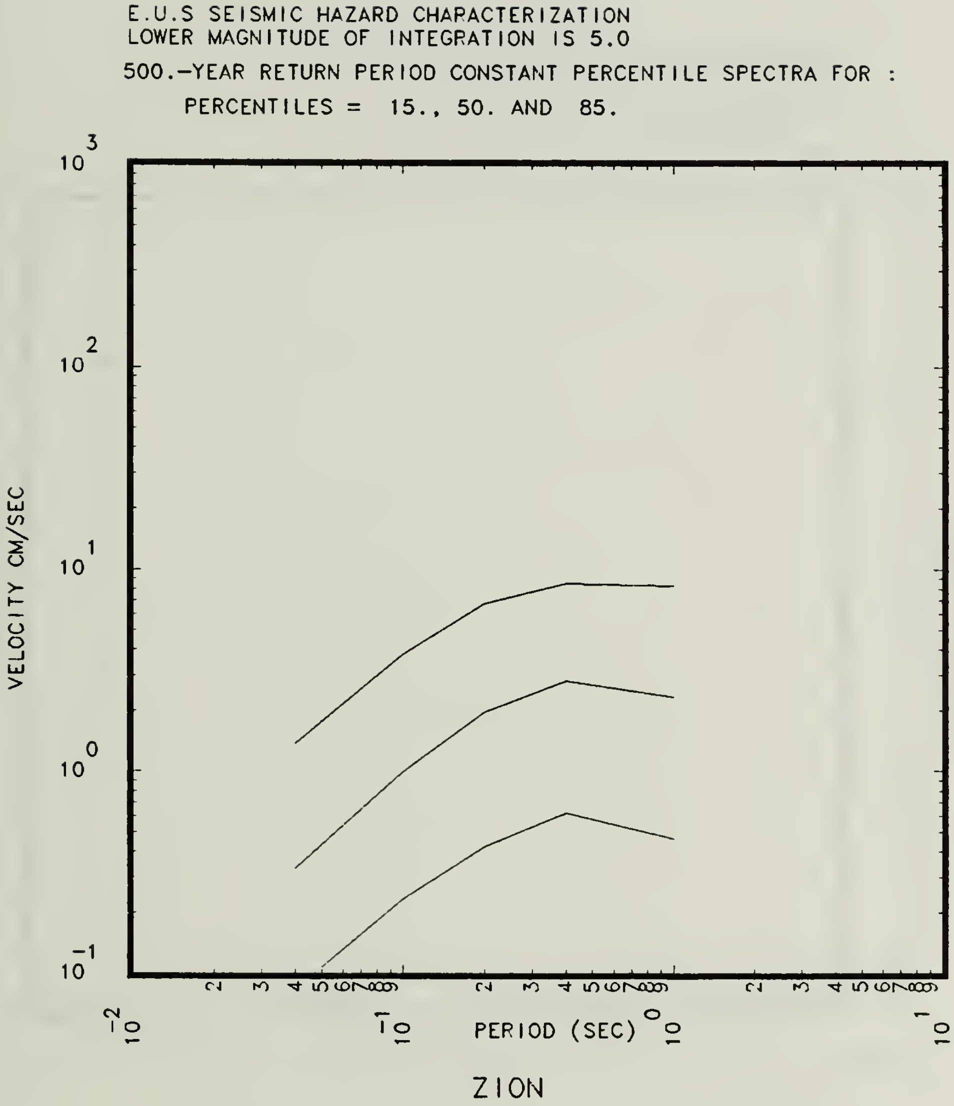


Figure 2.16.7 500 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Zion site.

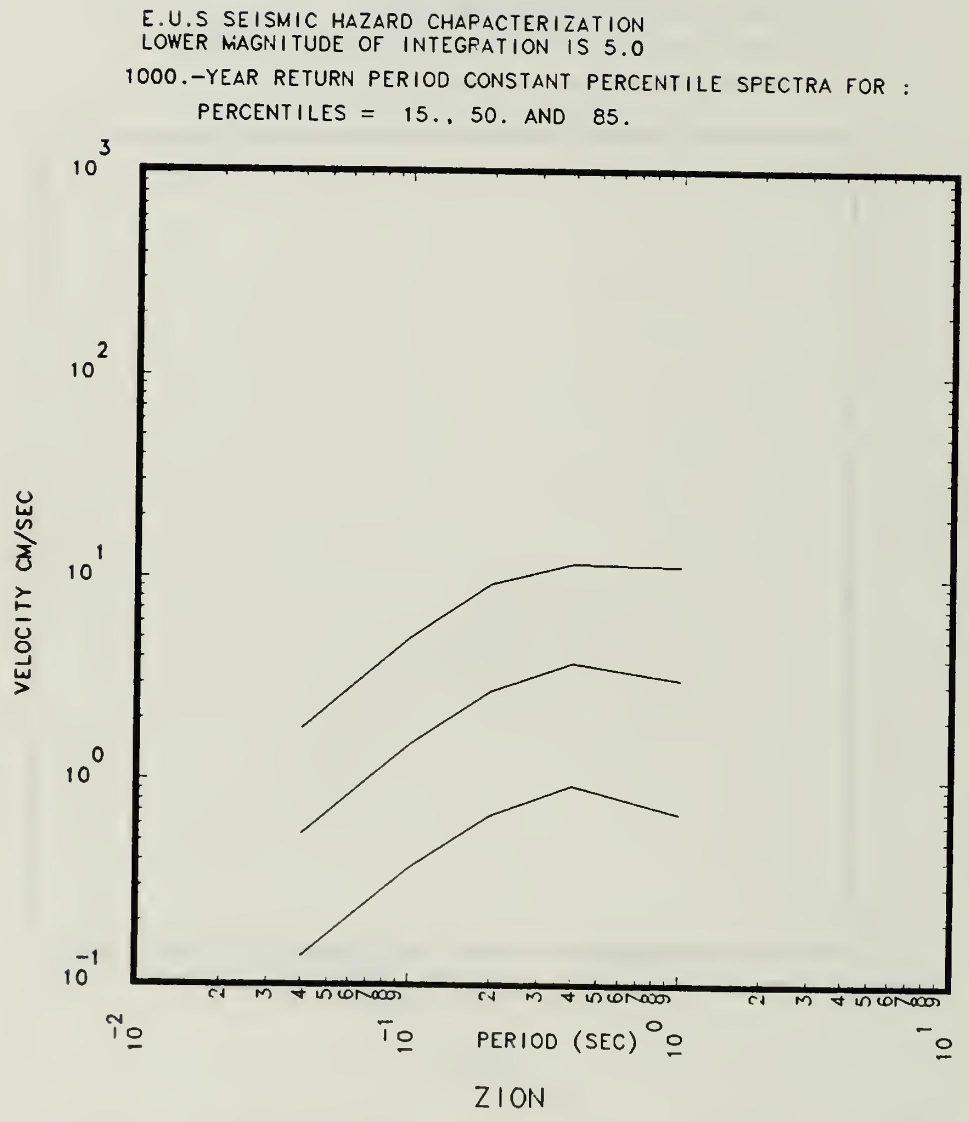


Figure 2.16.8 1000 year return period CPUHS for the 15th, 50th and 85th percentile aggregated over all S and G-Experts for the Zion site.

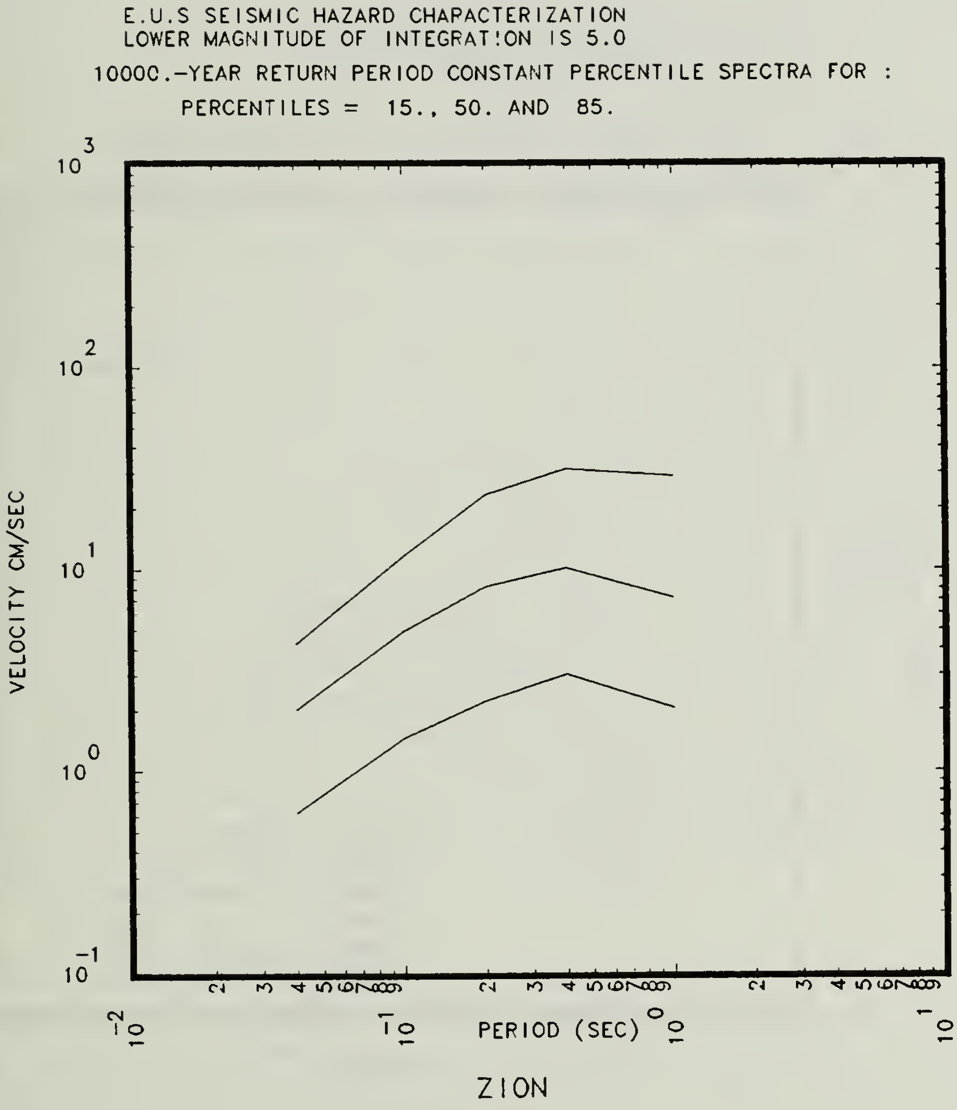


Figure 2.16.9 10000 year return period CPUHS for the 15th, 50th and 85th percentiles aggregated over all S and G-Experts for the Zion site.

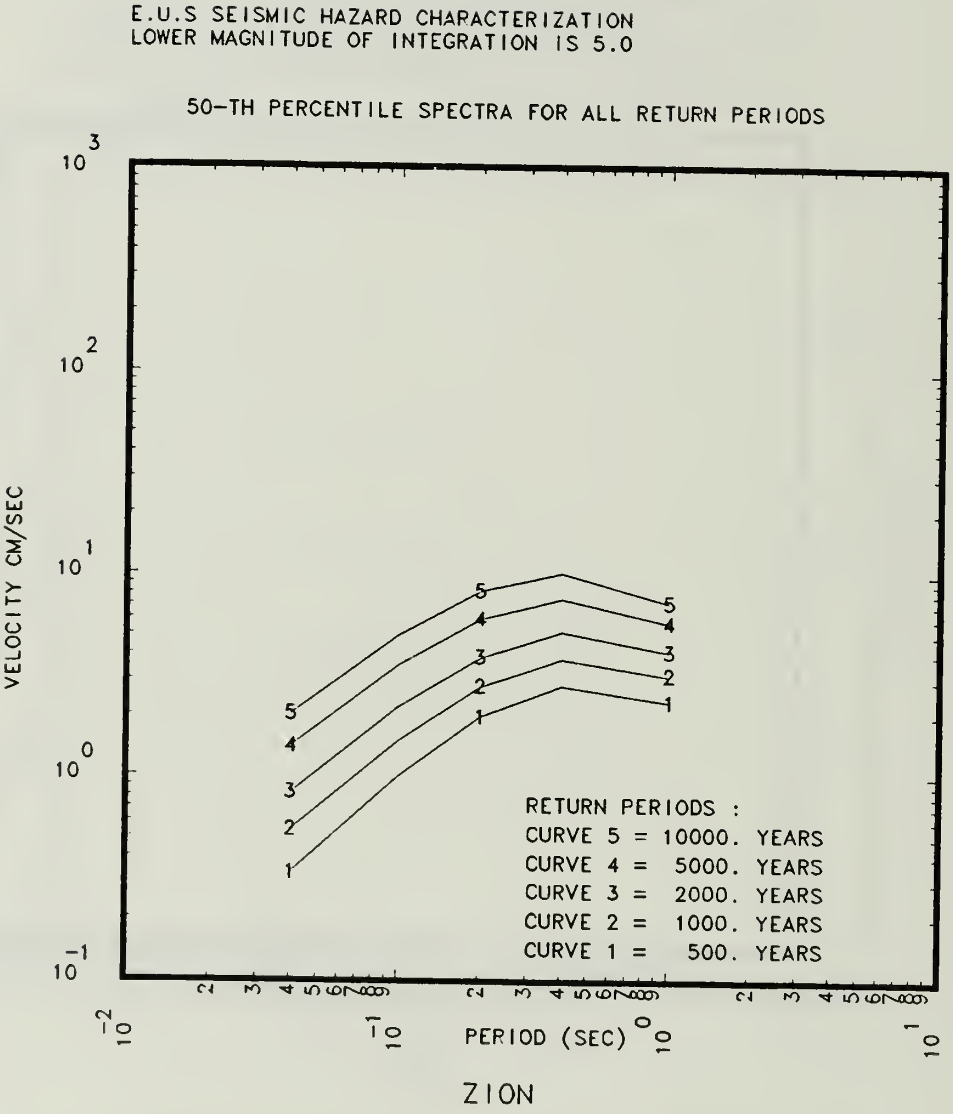


Figure 2.16.10 Comparison of the 50th percentile CPUHS for return periods of 500, 1000, 2000, 5000 and 10000 years for the Zion site.

3. GENERAL DISCUSSION, REGIONAL OBSERVATIONS, AND COMPARISONS BETWEEN SITES

3.1 Uncertainty

Section 2 shows that there are significant differences in the estimated seismic hazard for any site between various experts. In addition, each expert has expressed significant uncertainty about his own input. This uncertainty in turn leads to significant uncertainty in the aggregated estimate of the seismic hazard at any site. As explained in Volume I, we have used a Monte Carlo analysis to develop the distribution function for the seismic hazard at any site. In addition to the uncertainty in the probability distribution due to the variety of experts there is some small variability in the results due to the limitations on the number of simulations in our Monte Carlo uncertainty analysis to reasonably define the various estimators of the seismic hazard at a site. For example, in Fig. 3.1.1 we compare the CPHCs for PGA for two different sets of Monte Carlo runs for the Braidwood site. The Braidwood site was chosen because the uncertainty as measured by the spread between the BEHCs per S-Expert is as large as it is for any of the sites considered in this volume. Also, as noted in Section 2.3 there is a larger spread between the median and the 85th percentile CPHCs than between the 15th percentile and the median CPHCs indicating some departure from a lognormal distribution at the Braidwood site. We see from Fig. 3.1.1 that there are only slight differences between the bounds (as measured by the 15th and 85th percentile curves) and a slightly larger difference between the two median curves. For most sites, the difference between the median CPHCs for two different Monte Carlo runs is very small. As discussed in Section 3.1 of Vol. II, a detailed examination of the 2750 hazard curves generated in a Monte Carlo run for a typical site suggests that the distribution is approximately lognormal. However there are some sites where there is a departure from a lognormal distribution such as for the Braidwood or Fitzpatrick sites. For these exceptional cases, there is a slightly larger difference between the median curves obtained for two different Monte Carlo runs. However, as can be seen from Fig. 3.1.1 we can conclude that even in this worst case, differences between two Monte Carlo runs are not really large. It goes from practically no variability at low g values say, below 0.2g, to a maximum of ten to twenty percent around 0.6g. Nevertheless, these differences between two Monte Carlo runs must be kept in mind when making comparisons between nearby sites.

3.2 Sensitivity to Region Choice

In Volume I we indicated that we divided the EUS into four regions in order to give our G-Experts a chance to introduce regional corrections for attenuation and to give our S-Experts a chance to account for their varying expertise for different regions. The boundaries between these regions are very approximate. None of the sites considered in this volume are near the boundary, however, given the very approximate nature of the boundaries there is some interest in examining the sensitivity of "placement" on the results. The major impact of region placement is due to G-Expert 2's input. As can be seen from Tables 3.5 and 6 of Volume I, only G-Expert 2 introduced a regional

variation in his GM models. In region 1 he selected a different BE model than for regions 2,3 and 4. Thus the BEHC and BEUHS change depending upon whether the site is considered to be Region 1 or the other regions. In addition, it depends on whether it is a rock or a soil site with the effect being larger for a soil site than for a rock site.

In Section 3.2 of Vol. II we examined the sensitivity of results to placement and found that overall for the sites located near the border between what we have defined as region 1 and the other regions, it makes very little differences on the CPHCs and CPUHS whether we say the sites are located in region 1 or the other regions. It makes some differences in the BEHCs and AMHCs, particularly for soil sites. But given the overall uncertainty, as measured by the spread between the 15th and 85th percentile CPHCs, the sensitivity is small and negligible.

3.3 Factors Influencing Zonal Contribution to the Hazard

A number of factors influence how significantly a given seismic source zone contributes to the hazard at any given site for any given S-Expert. Several factors are obvious and a few may not be so obvious. The main factors that influence zonal contribution to the hazard can be separated into three groups:

1. Attributes of the zone in question:
    - Distance from the zone to the site.
    - The rate of activity in the zone.
    - The b-value used for the zone.
    - The upper magnitude cut off for the zone.
    - The probability of existence of the zone.
    - The size of the zone.
2. Attributes of the ground motion model:
    - The rate at which the peak ground motion attenuates with distance.
    - The site's soil category.
3. Attributes of the hazard analysis methodology:
    - Uncertainty analysis performed.
    - Lower bound of integration for magnitude.

Let us start our discussion on the significance of the above factors in the inverse order, i.e. start with the set listed under (3) above. We made the point in Section 2 that the Tables 2.SN.1 were based only on BE input and thus did not in all cases capture the true contribution of a given zone to the hazard for a specific site. The contribution of a given zone listed in Tables 2.SN.1 might be too high if a zone's probability of existence is relatively low but greater than or equal to 0.5. On the other hand it is too low (not listed) if the probability of existence is less than 0.5.

In our analysis the modeling uncertainty in the site correction is accounted for by allowing for several different types of corrections to be performed. The type of correction performed also can influence how the ground motion model (or models) impact the seismic hazard and how correction for the site's soil category is made. This will be discussed later. Other elements of the uncertainty analysis such as the variation in zone boundary shape, variation in rate of activity etc. are less important and generally do not play a major role in determining the zonal contribution to the hazard.

The lower bound for magnitude used in the analysis is of some significance at the low g-value end. This is illustrated in Figs. 3.3.1a and b. In Fig. 3.3.1a we show the contribution to the BEHC for PGA from all the earthquakes in four distance rings about the Braidwood site when the lower bound of integration for magnitude is 5.0. Similarly in Fig. 3.3.1b we show the same thing except the lower bound of integration has been reduced to 3.75. We see by comparing Fig. 3.3.1a to 3.3.1b that, when the lower bound of integration is lowered to 3.75, the region from $0 \leq$ Distance ≤ 15 contributes significantly more to the hazard at lower PGA levels and there is also a large increase in contribution to the hazard from the region $15 \leq$ Distance ≤ 50. At high PGA levels there is little effect of changing the lower bound of integration. Of course, if the lower bound was yet even higher than 5, the effect would be more significant even to much higher PGA levels.

Let us now address group (2) - attributes of the GM model. First, let us note if there was no modeling uncertainty, i.e., if we knew the correct form for the GM model then the attributes of the GM model would not influence the zonal contribution. If no uncertainty analysis is being performed, e.g. Algermissen et. al. (1982) then it is the same as saying we know the correct form for the GM model. In our analysis we have included uncertainty about GM modeling in three ways:

(1) We used multiple GM models.
(2) We introduced multiple ways to correct for the effect that the site's soil category has on the estimated ground motion.
(3) We varied the random uncertainty associated with each GM model.

All three of the above are important.

In Section 2.3 we have already made the point that one of the BE GM models has a significantly lower attenuation rate than the other BE GM models. This can make a significant difference. In Fig. 3.3.1a we show the contribution to the BEHC for PGA from the earthquakes located in four distance ranges when all the BE GM models are used for the Braidwood site. In Fig. 3.3.2 we show the same thing as in Fig. 3.3.1a except only G-Experts 1-4's BE GM models are used. That is, we have eliminated the GM model with the low attenuation. It is evident from comparing Figs. 3.3.1a and 3.3.2 that the uncertainty about the correct GM model is very significant and can have an important impact on determining which zones contribute to the hazard at a site.

The site's soil category has a significant influence because our uncertainty about how to correct the GM for the soil conditions at a site impacts the estimate of the ground motion at a site from an earthquake differently for various ground motion models. This is illustrated by comparing Figs. 3.3.1a to 3.3.3. As noted, in Fig. 3.3.1a we show the contribution to the BEHC for PGA for four distance ranges for the Braidwood site. The Braidwood site is a rock site. In Fig. 3.3.3 we show the contribution to the BEHC for PGA for the same four distance ranges for the LaSalle site. The LaSalle site is in the till-2 soil category. We see from Fig. 1.1 that LaSalle (plot symbol B) and Braidwood (plot symbol 3) are located relatively near each other, thus we would expect little difference in the seismic hazard between these two sites. We see however from comparing Figs. 3.3.1a and 3.3.3 that there is a considerable difference between the two sites in the distance ranges which contribute most to the BEHCs for PGA. Thus if Table 2.3.1 is compared to Table 2.11.1 we see some significant differences. Most of these differences arise from the differences in the estimates of the PGA for a given earthquake at the two sites due to the correction for site soil conditions.

It should be noted that the differences between which distance bands contribute most to the BEHCs for PGA for rock sites as compared to soil sites is not typically the difference between Figs. 3.3.1a and 3.3.3 for the set of BE GM models G-Experts selected by our study. There is some variation between the various rock sites and the various soil sites depending upon their location. For example, by comparing Figs. 3.3.4a and b to Figs 3.3.1a and 3.3.3 we see that there is a difference in which distance ranges contribute most to the BEHCs for PGA for sites (Braidwood and LaSalle) located at moderate distances from the New Madrid region as compared to sites (Perry and Beaver Valley) located at large distances from the New Madrid region. It should also be noted that the distance ranges which contribute most to the BEHCs changes for sites located even nearer to the New Madrid region than the LaSalle site as can be seen from Fig. 3.3.5. In Fig. 3.3.5 we give, for the Clinton site the contribution to BEHC for PGA for the same four distance ranges used in the preceding figures. It can be seen from Fig. 1.1 that the Clinton site is the site closest to the New Madrid region.

The group (1) - attributes of the zone in question-are relatively easy to understand and are generally the factors which we expect to control a given zone's contribution to the seismic hazard at a site. In Section 2 we gave examples of how the group (1) factors influence this contribution.

From the above discussion we can conclude that care must be taken when using the information given in Table 2.1.1 to 2.16.1. The information is useful, but, as indicated, it can give a distorted picture of which zones are most significant. Unfortunately, in complex cases the only way to get an undistorted understanding is to perform a detailed sensitivity analysis. However, one can gain a relatively good understanding of what is important by carefully examining the data given in Tables 2.SN.1, the zonation maps for each S-Expert, the seismicity data for each S-Expert given in Vol. I Appendix B and keeping in mind the sensitivities discussed in this section.

3.4 Comparisons of the Seismic Hazard Between Sites

In this project the seismic hazard has been defined as the annual probability of exceedance of a given level of peak ground motion. Thus, strictly speaking, we only need to compare hazard curves between sites to reach a conclusion about the relative hazard at various sites. However, given the large uncertainties that exist in our estimate of the peak ground motion and our inability to convert a given level of peak ground motion into a risk number, suggests that we need to also introduce some subjective judgement into the process of assessment of the relative hazard between sites. In this section we compare the computed seismic hazard between sites. In addition we examine some important elements that should be factored into an assessment of the relative difference in the seismic hazard between the sites located in Batch 3.

When comparing the hazard between two sites, one of the most important factors to be considered is the potential difference in soil categories between the two sites. For example, in Fig. 3.4.1 we compare the median CPHC for the Braidwood site to the median CPHC for the LaSalle site. We see from Fig. 1.1 that these two sites are nearby each other hence we would generally expect that there would be little difference between the seismic hazard for these two sites. However, as can be seen from Fig. 3.4.1, there is considerable difference in the hazard between these two sites. The reason for this difference is the fact that Braidwood is a rock site and LaSalle is a soil site (Category Till-2). A complete discussion on the local site effects on ground motion is given in Volume VI, however, Fig. 3.4.1 shows that it is very significant. The uncertainty surrounding the correction for local site effects makes it difficult to unequivocally conclude that the seismic hazard is higher at the LaSalle site than at the Braidwood site.

In addition to soil category, one must consider which estimator of the hazard should be used because in some cases different estimators would lead to different conclusions about the relative hazard between two sites. For example, if Fig. 2.3.1 is compared to Fig. 2.11.1 we see that both the AMHC and BEHC are higher at the Braidwood site than at the LaSalle site yet the median CPHC is significantly higher at the LaSalle site than at the Braidwood site as shown in Fig. 3.4.1. If Fig. 2.3.3 is compared to Fig. 2.11.3 we see that there is little difference between the 15th CPHCs and not too much difference between the 85th CPHCs at the two sites. The main reason the BEHC and AMHC are so "high" at the Braidwood site as compared to LaSalle can be seen by comparing Fig. 2.3.11 to Fig. 2.11.11 which gives the spread between BEHCs per G-Expert for a particular S-Expert (different S-Experts are shown here but each are typical for these two sites). We see for Braidwood that one G-Expert is much higher than the others, where as at LaSalle the BEHCs for all G-Experts are about the same. The high outliers tend to raise both the BEHC and AMHC at the Braidwood site.

Most of the comparisons made in the rest of this section will be relative to the median hazard curve because it proved to be the most stable parameter. Generally, the spread between the 15th and 85th CPHCs gives an idea of

uncertainty at a given site, however, as we have seen at the Braidwood site, this spread may not fully capture the distribution of the uncertainty, that is, if the distribution of simulated hazard curves departs from a lognormal distribution such as occurred at the Braidwood site there will generally be a larger spread between the 50th and 85th CPHCs than the 15th and 50th CPHCs.

As one would expect, the hazard is not uniform over the sites in Batch 3 as is shown in Fig. 3.4.2. In Fig. 3.4.2 we compare the median CPHCs for four rock sites spread across region 3. It can be seen from Fig. 3.4.2 that there is a variation in the seismic hazard in the region. It is interesting to note that the rock site (Davis Besse) in Batch 3 with the highest hazard is relatively far from the New Madrid zones.

It is somewhat instructive to compare the contribution to the BEHCs for various magnitude and distance ranges between the four sites plotted in Fig. 3.4.2. The contribution to BEHCs from earthquakes in 4 magnitudes ranges are given in Figs. 2.3.4 for the Braidwood site, Fig. 2.7.4 for the Davis Besse site, Fig. 2.13.4 for the Perry site, and Fig. 2.15.4 for the Quad cities site. Comparing these figures we see some differences between the sites. For example, larger magnitude earthquakes contribute more significantly to the hazard at the Braidwood and Quad Cities sites than at the Perry and Davis Besse sites.

Figure 3.3.1.a gives the contribution to the BEHC for the Braidwood site from four distance ranges and Fig. 3.3.4a for the Perry site. The relative contribution to the BEHC for the Quad cities site for the four distance ranges is similar to the Braidwood site and hence, does not need to be repeated. Similarly, the relative contribution to the BEHC for PGA for the four distance ranges for the Davis Besse site is similar to the Perry site shown in Fig. 3.3.4a. We see by comparing Figs. 3.3.1a to 3.3.4a that for the rock sites within several hundred kilometers of the New Madrid region that earthquakes at distances greater than 150 km contribute most to the BEHC for PGA. For sites at greater distances from the New Madrid region, the New Madrid region is less important and the zones nearby the site contribute most to the BEHC for PGA. For example, examination of the maps for the S-Experts shows that many S-Experts' have a zone which includes or is near the Davis Besse site.

In Fig. 3.4.3 we compare the median CPHCs for the Clinton, LaSalle and Kewaunee sites. These three sites are in the till-like 2 category. As expected the sites closer to the New Madrid region have a higher hazard than sites at larger distances such as Kewaunee. However, it is somewhat of a surprise that at high PGA levels the median CPHC at LaSalle is the same as at Clinton. The explanation for this can be seen by comparing Figs. 2.5.4 to 2.11.4 (relative contribution of various magnitude ranges) and Figs. 3.3.3 to 3.3.5 (relative contribution of various distance ranges). We see from these comparisons that at the low g value end that the larger, more distant earthquakes from the New Madrid region are the most important contributor to the BEHC for PGA. Hence, because the Clinton site is nearer to the New Madrid zone, the hazard is higher at Clinton than at LaSalle. However, at the higher PGA levels, smaller close-by earthquakes become as significant as the large

more distant earthquakes from the New Madrid region. If the maps for the various S-Experts are examined we see that, in general, the LaSalle site is more likely to be in a local zone or near to a local zone than the Clinton site. Thus the hazard from nearby earthquakes is higher at the LaSalle site than at the Clinton site. This is just enough to cancel the effect of the Clinton site being nearer the New Madrid zones.

There can be some variation in the seismic hazard between relatively nearby sites in region 3. In Fig. 3.4.4 we compare the median CPHC for the Davis Besse site to the median CPHC for the nearby Fermi site. If the S-Experts' maps and Tables 2.7.1 and 2.9.1 are examined we see that the Davis Besse site is in S-Expert's zone 9 whereas Fermi is not. Also for S-Expert 1 Fermi is nearer to the edge of S-Expert 1's zone 19 than Davis Besse, similarly relative to S-Expert 3's zone 11, similarly relative to S-Expert 6's zone 9 and relative to S-Expert 10's zone 26. In addition the Davis Besse site is closer to S-Expert 5's zone 12 than Fermi, similarly relative to S-Expert 13's zone 7. Thus the hazard is higher at the Davis Besse site than at the Fermi site.

In Fig. 3.4.5 we compare the median CPHC for the Zion site to the median CPHC for the relatively nearby Palisades site. If the S-Experts' maps are examined and Tables 2.12.1 is compared to 2.16.1 we see that the Zion site is located either in or nearby more local zones than the Palisades site; hence the hazard is higher for the Zion site than at the Palisades site. It should be noted that the median CPHC for the Cook site falls between the median CPHCs for the Zion and Palisades sites.

It is also of some interest to note that there is no difference in the hazard between the Braidwood, Byron and Dresden sites. However, as can be seen from Fig. 3.4.2 the hazard is somewhat lower at the Quad Cities site. The Quad Cities site is somewhat lower because, as can be seen from the S-Experts' maps, the Quad Cities site is generally further away from the local zones introduced by various S-Experts than the Braidwood, Byron or Dresden sites.

The spectral curves show much the same differences between sites as the PGA curves. However because the spectral ordinates are plotted on a log scale whereas the PGA is plotted on linear scale, the differences between sites are more noticeable for PGA comparisons than for spectral comparisons. Nevertheless some interesting differences can be observed by making spectral comparisons. For example, in Fig. 3.4.6a we compare the 10,000 year return period median CPUHS for the Braidwood and Perry sites. We pointed out earlier that smaller nearby earthquakes are more significant at the Perry site than at the Braidwood site. The shapes of the CPUHS for the two sites reflect this. We see from Fig. 3.4.6a that the CPUHS for the Perry site less long period energy at the Braidwood site. This effect can be seen also in Fig. 3.4.6b where we compare the 10,000 year return period median CPUHS for the Clinton and Kewaunee sites. We pointed out earlier that, relatively speaking, large earthquakes were significant at the Clinton site than at the Kewaunee site. The shape of the CPUHS curves reflect this effect at the long period end of the spectrum.

In Fig. 3.4.7 we compare the median CPHCs between all of the sites listed in Table 1.1. The variation between sites includes the variation in zonation and site conditions. We see from Fig. 3.4.7 that at g-levels below 0.3g the Clinton site has the highest median CPHC whereas above 0.3g the Beaver Valley site has the highest median CPHC. We also see that at g-levels below 0.3g the Big Rock Point site has the lowest median CPHC and at above 0.3g that the Quad Cities site has the lowest median CPHC. It should be noted that if other estimates of the hazard were used we reach different conclusions. For example in Fig. 3.4.8 we show an interesting plot.

According to Fig. 3.4.8, the four sites with the highest probability of exceedance of 0.2g are sites number 3, 5, 8 and 15 (see Table 1.1) when the estimator is the arithmetic mean (A). When the 85th percentile (*) is the estimator, the four sites are sites number 5, 7, 8 and 11. They are sites 3, 5, 7 and 8 when the best estimate (B) is used, and finally they are sites 1, 5, 11 and 16 when the estimator is the median hazard.

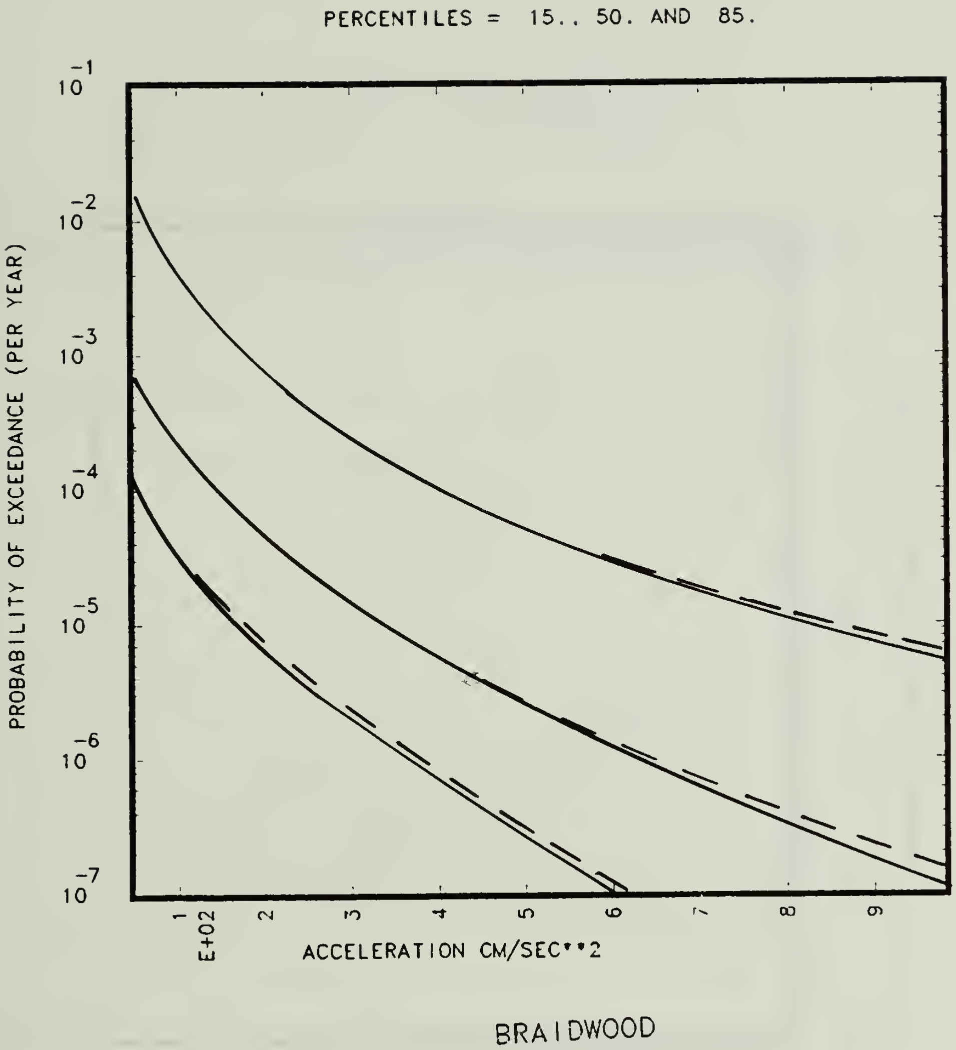


Figure 3.1.1 Comparison of the 15th, 50th and 85th percentile CPHCs for PGA between two Monte Carlo runs for the Braidwood site.

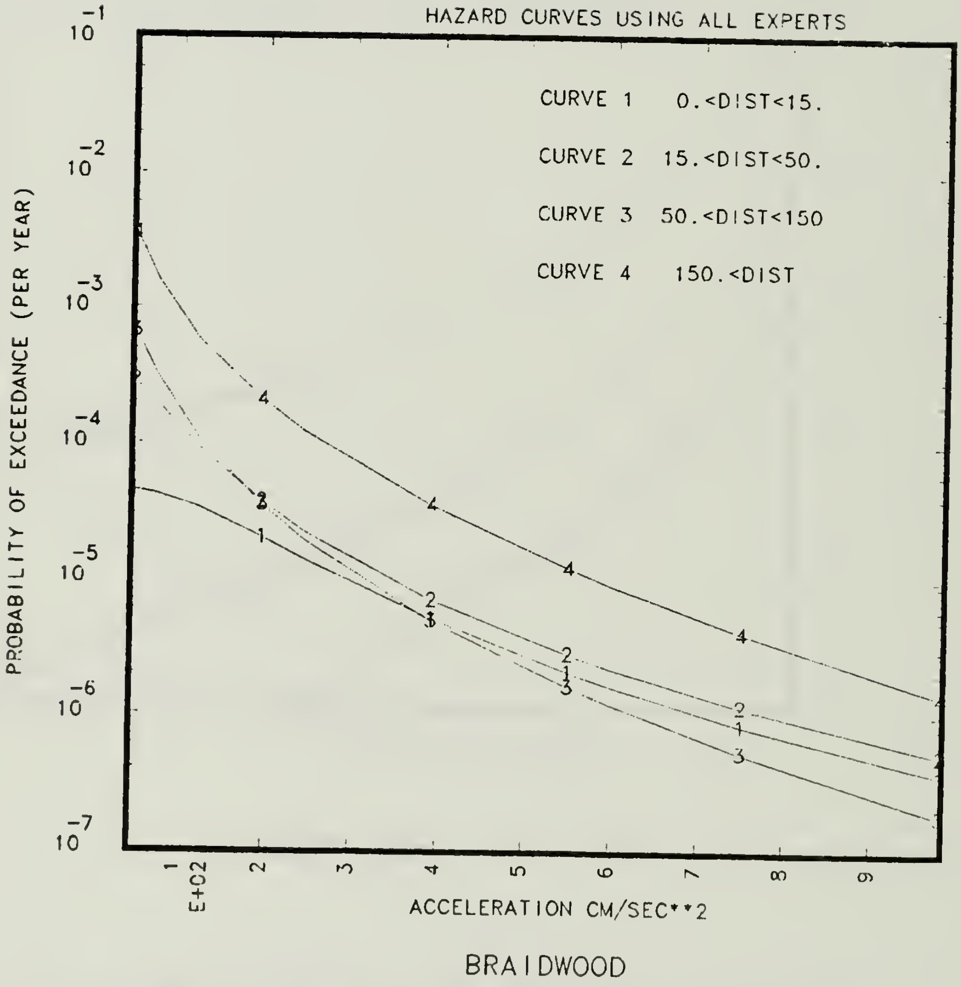


Figure 3.3.1a BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated distance ranges for the Braidwood site when the lower bound of integration for magnitude is 5.0.

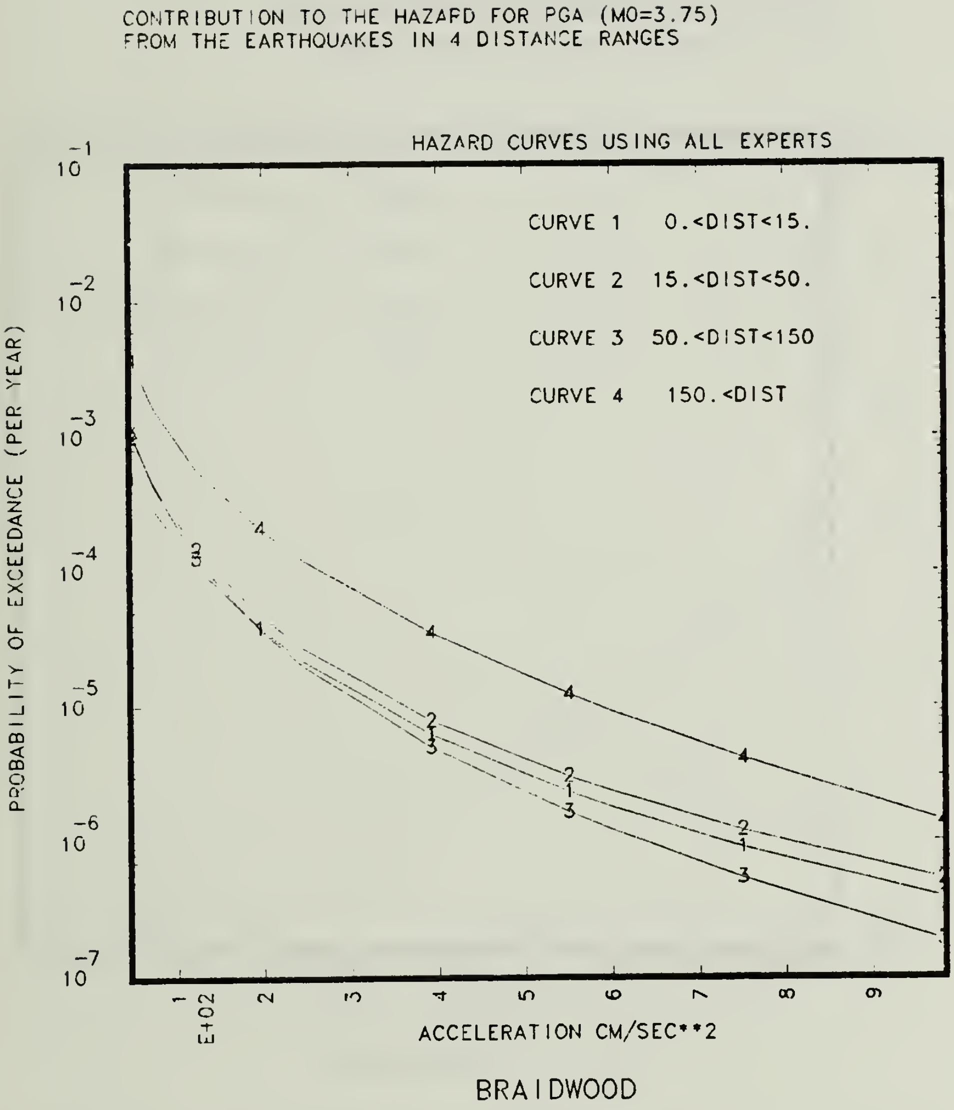


Figure 3.3.1b Same as Fig. 3.3.1a except the lower bound of integration for magnitude was 3.75.

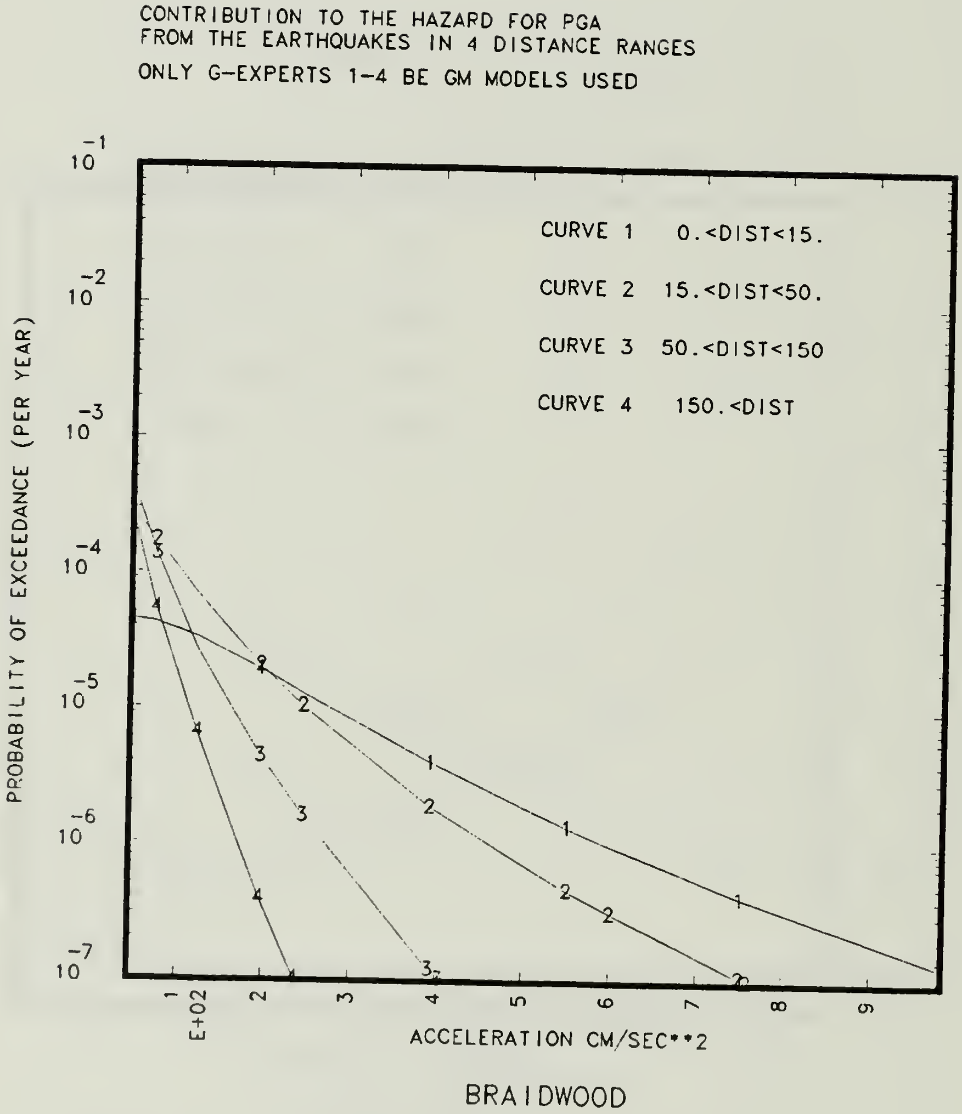


Figure 3.3.2 BEHCs which include only the contribution of the PGA hazard from earthquakes within the indicated distance ranges for the Braidwood site. Only G-Experts' 1-4 BE GM models are used. The lower bound of integration for magnitude is 5.0.

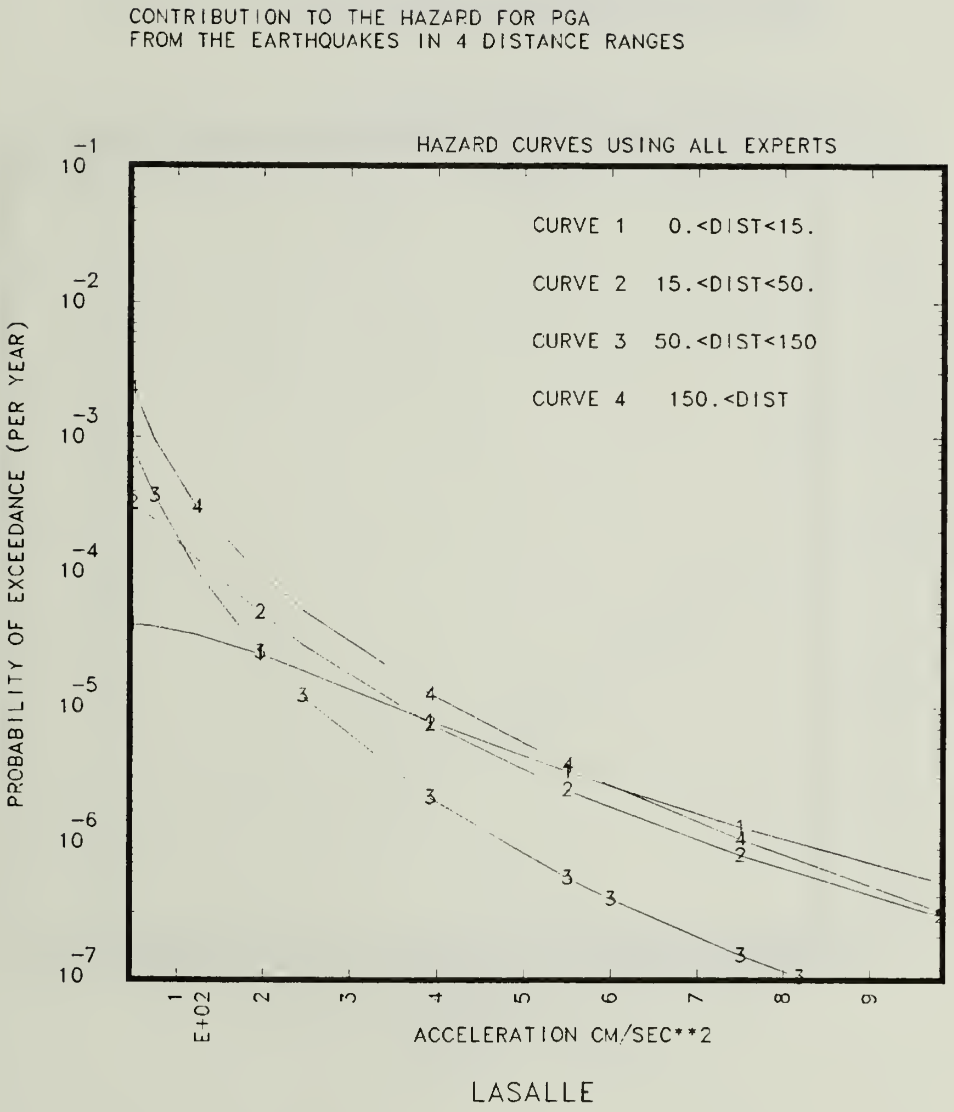


Figure 3.3.3 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated distance ranges for the LaSalle site when the lower bound of integration for magnitude is 5.0.

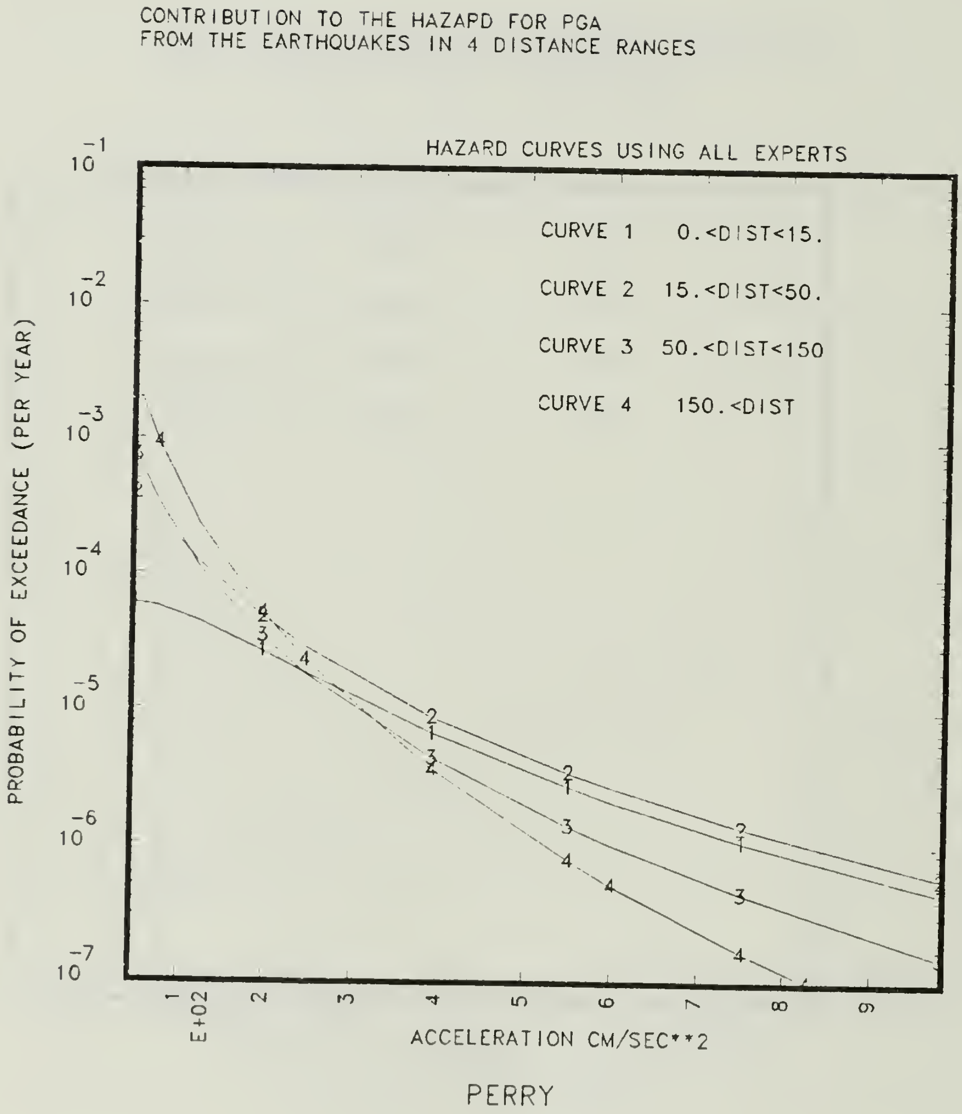


Figure 3.3.4a BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated distance ranges for the Perry site (rock site) located at a large distance from the New Madrid region.

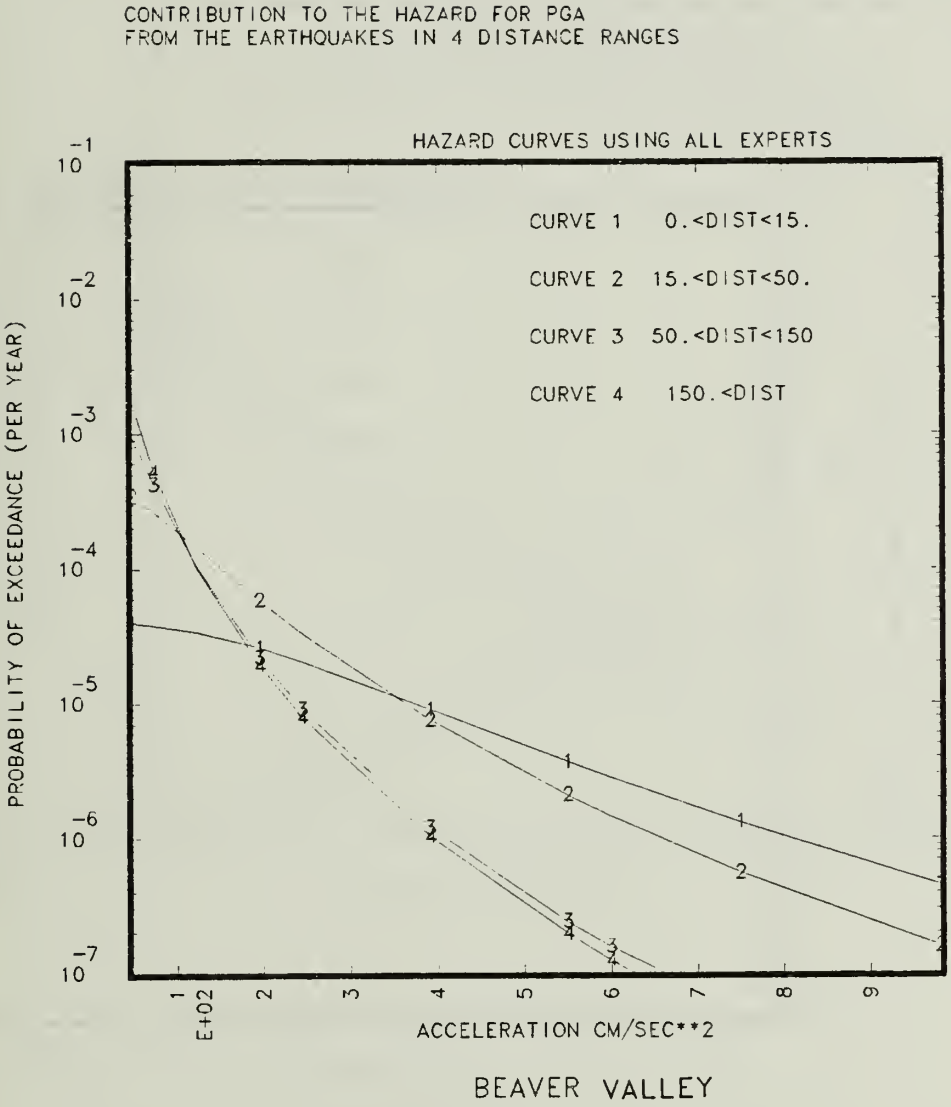


Figure 3.3.4b BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated distance ranges for the Beaver Valley site (soil site) located at a large distance from the New Madrid region.

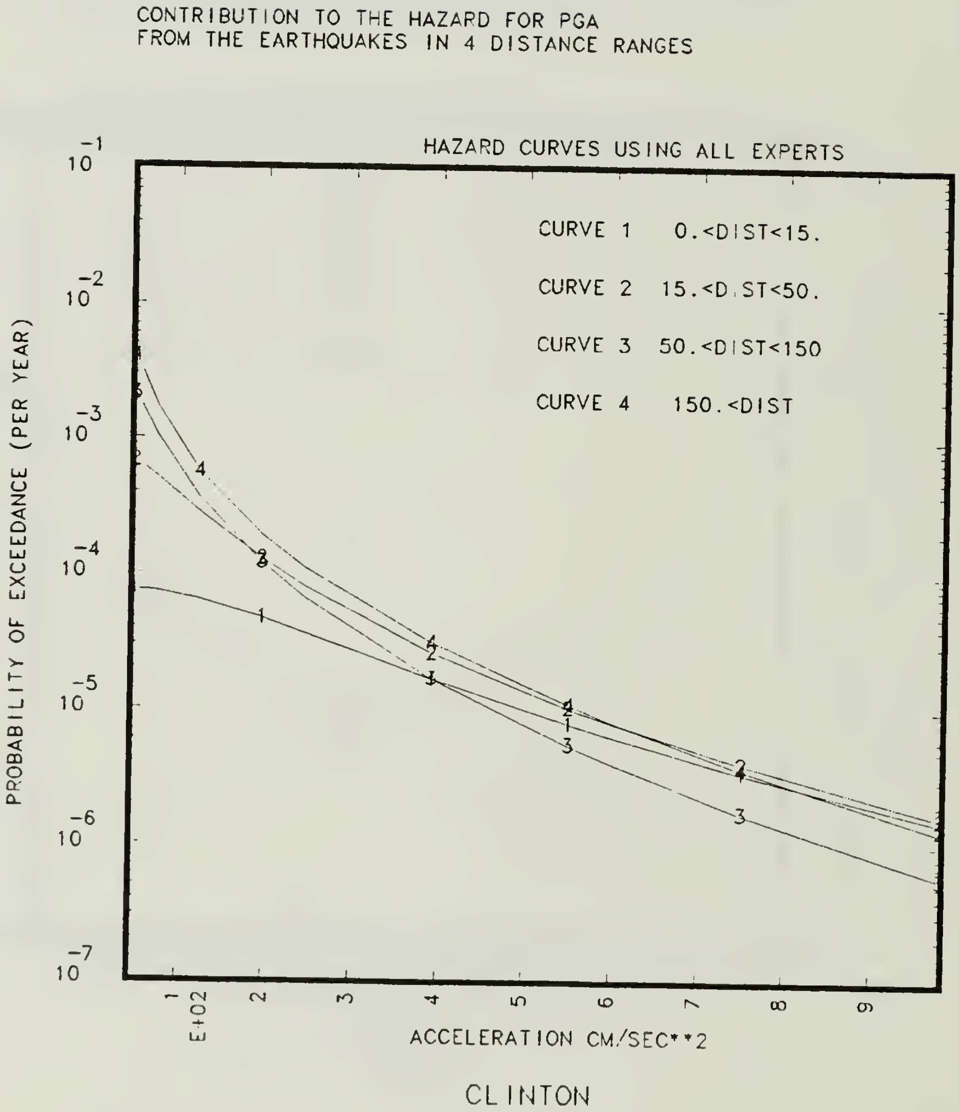


Figure 3.3.5 BEHCs which include only the contribution to the PGA hazard from earthquakes within the indicated distance ranges for the Clinton site (soil site). The Clinton site is the site closest to the New Madrid region.

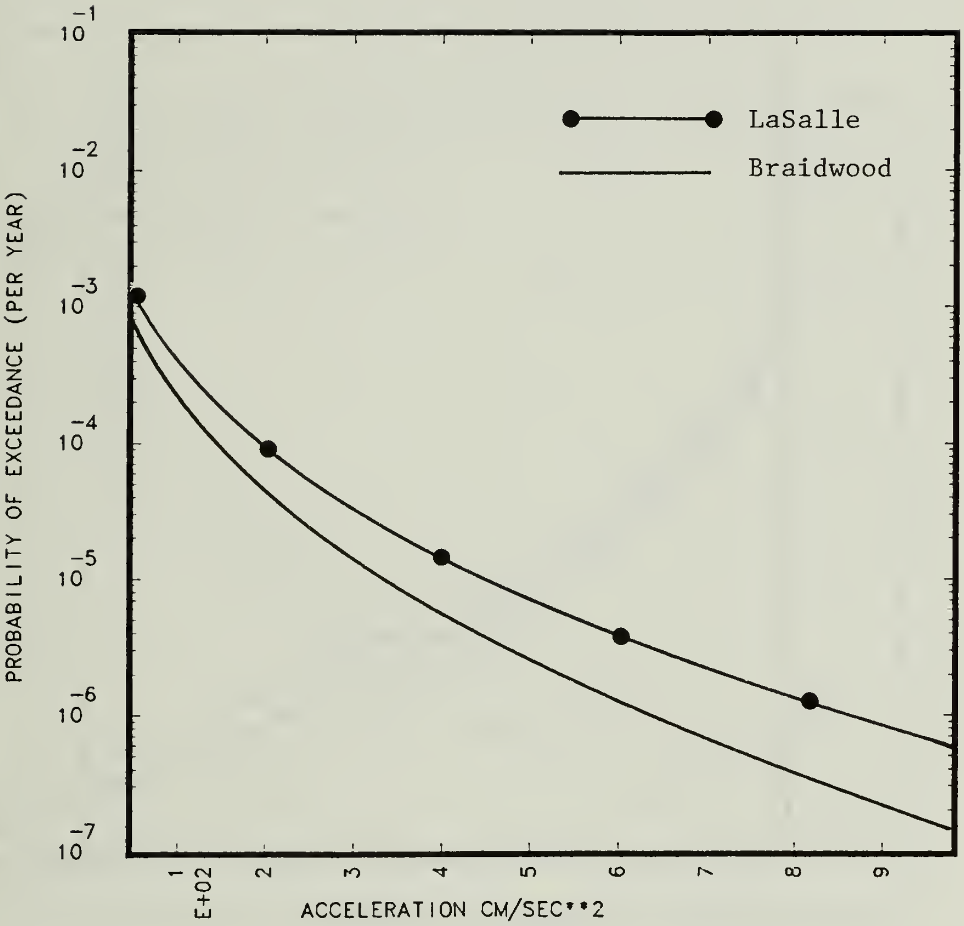


Figure 3.4.1 Comparison of the median CPHCs for PGA between a nearby rock site (Braidwood) and a soil site (LaSalle).

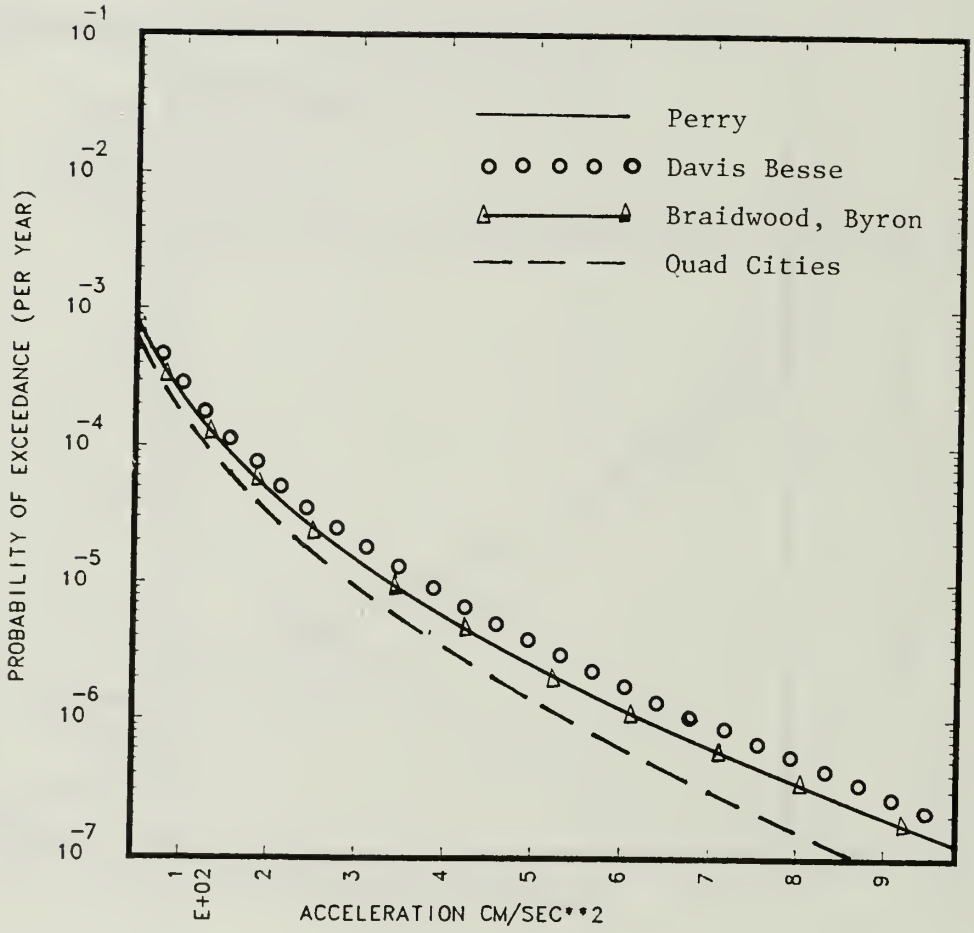


Figure 3.4.2 Comparison of the median CPHCs for PGA for the four rock sites indicated.

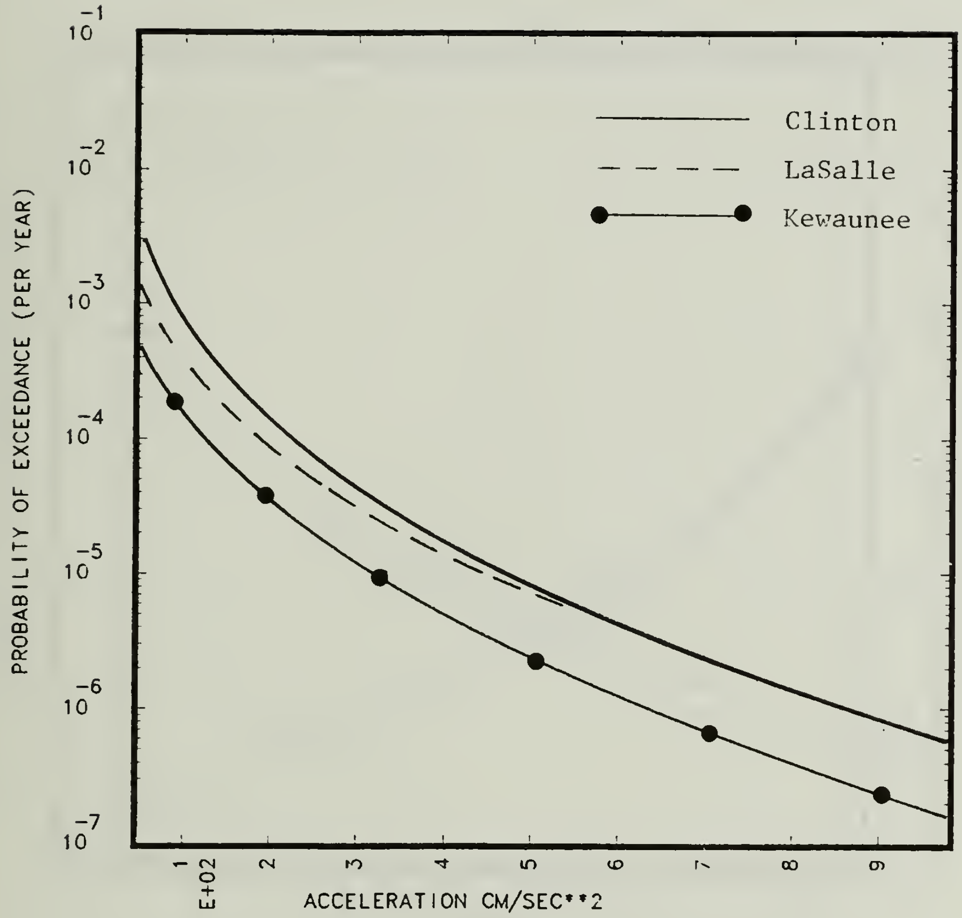


Figure 3.4.3 Comparison of the median CPHCs for the three Till-like 2 soil category sites in the Batch 3 set of sites.

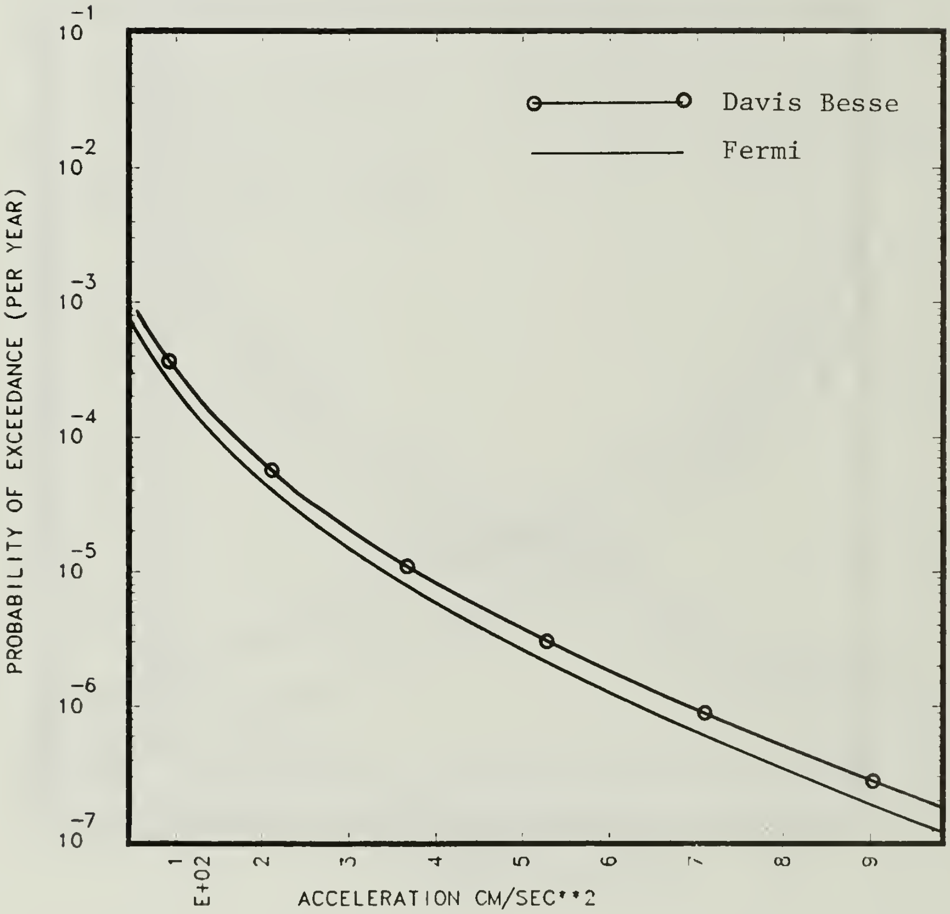


Figure 3.4.4 Comparison of the median CPHCs between two relatively nearby rock sites.

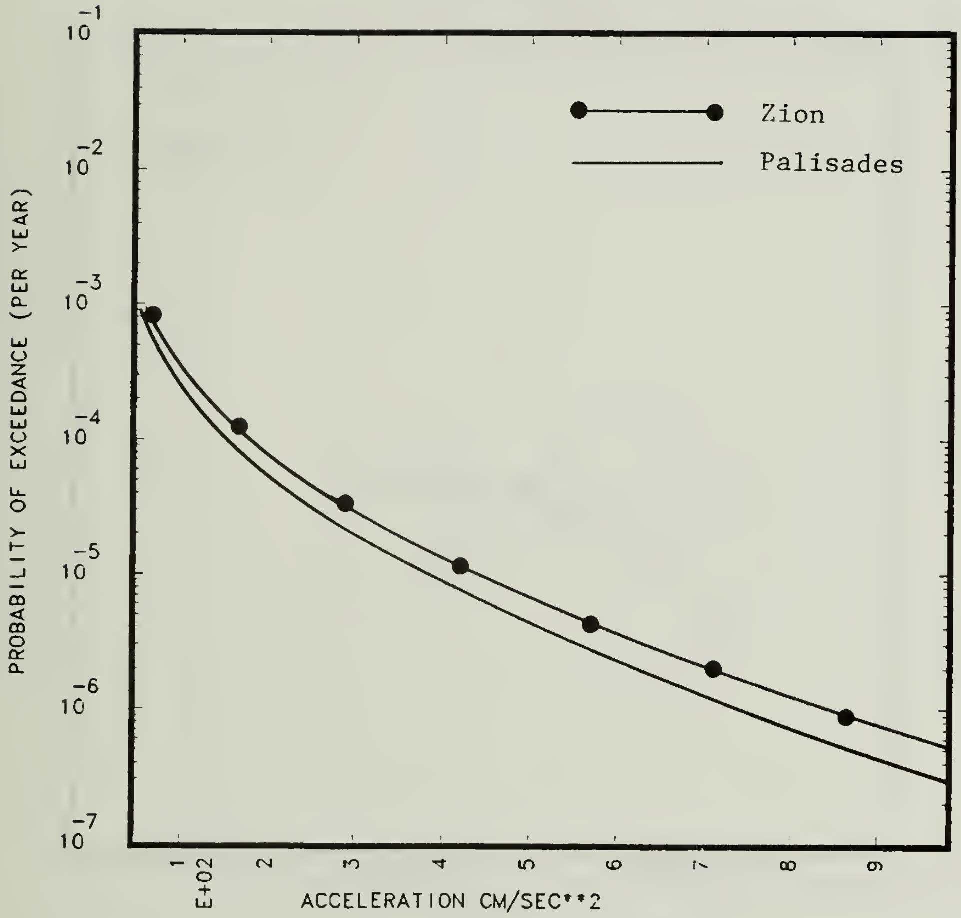


Figure 3.4.5 Comparison of the median CPHCs between two relatively nearby Sand-like 2 sites.

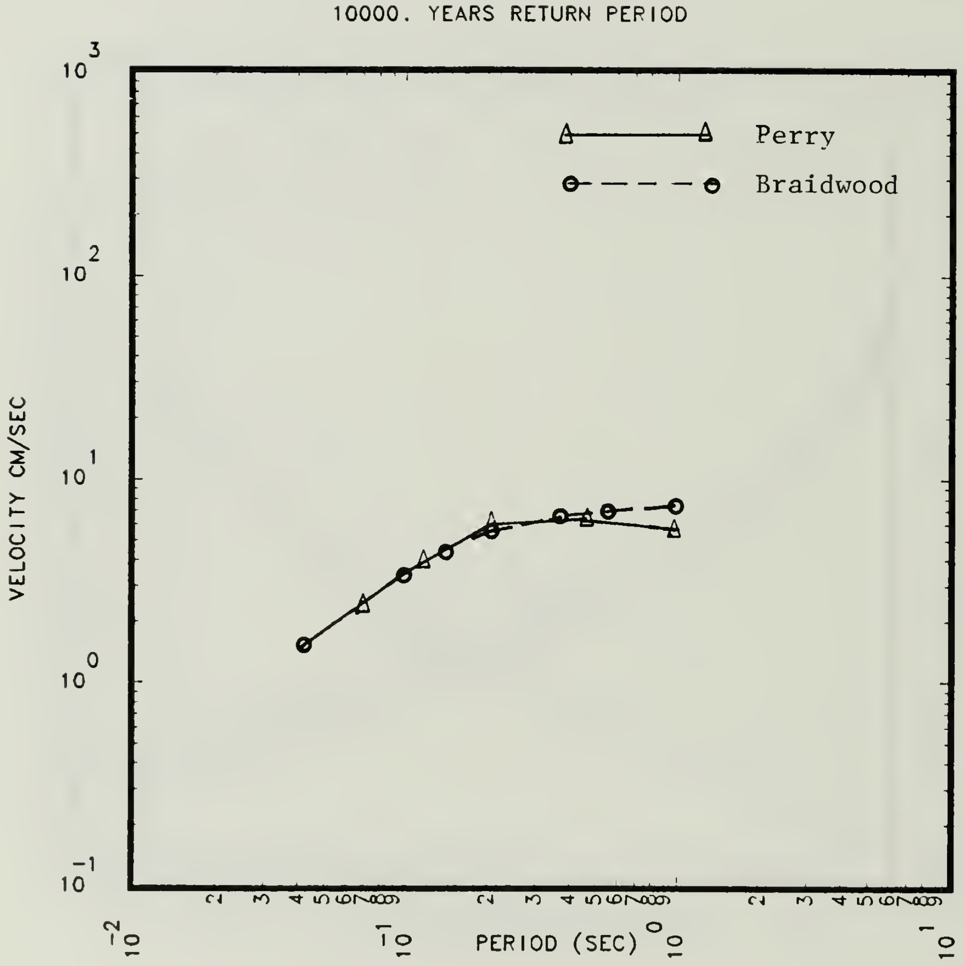


Figure 3.4.6a Comparison of the median 10,000 year return period CPUHS between the Braidwood and Perry sites.

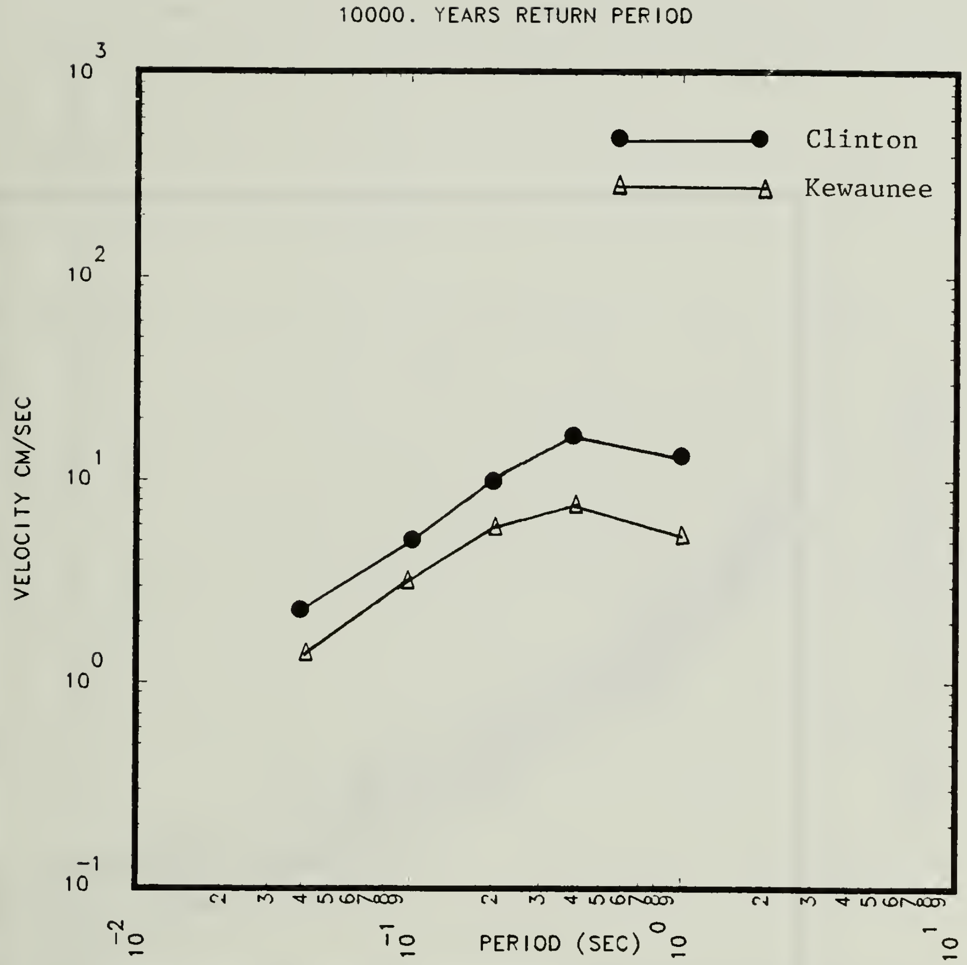


Figure 3.4.6b Comparison of the median 10,000 year return period CPUHS between the Clinton and Kewaunee sites.

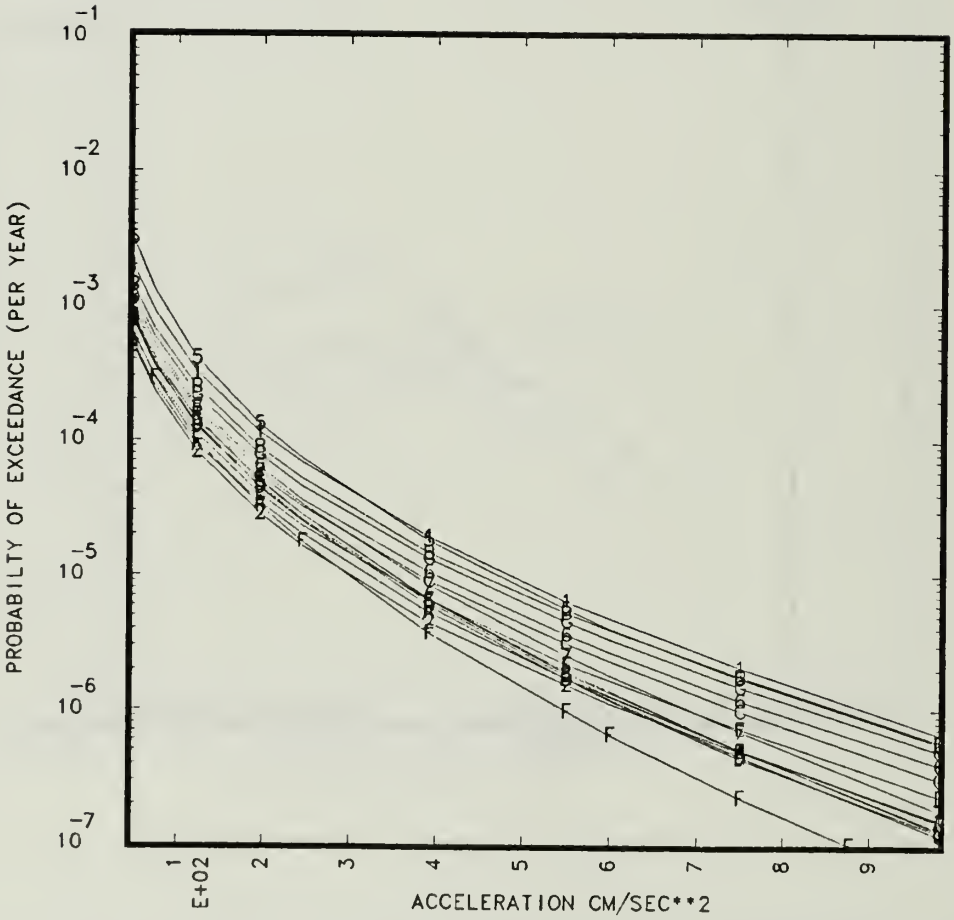


Figure 3.4.7 Comparison between the median CPHCs for PGA for all of the sites in Batch 3. The various sites are identified by the symbols in Table 1.1.

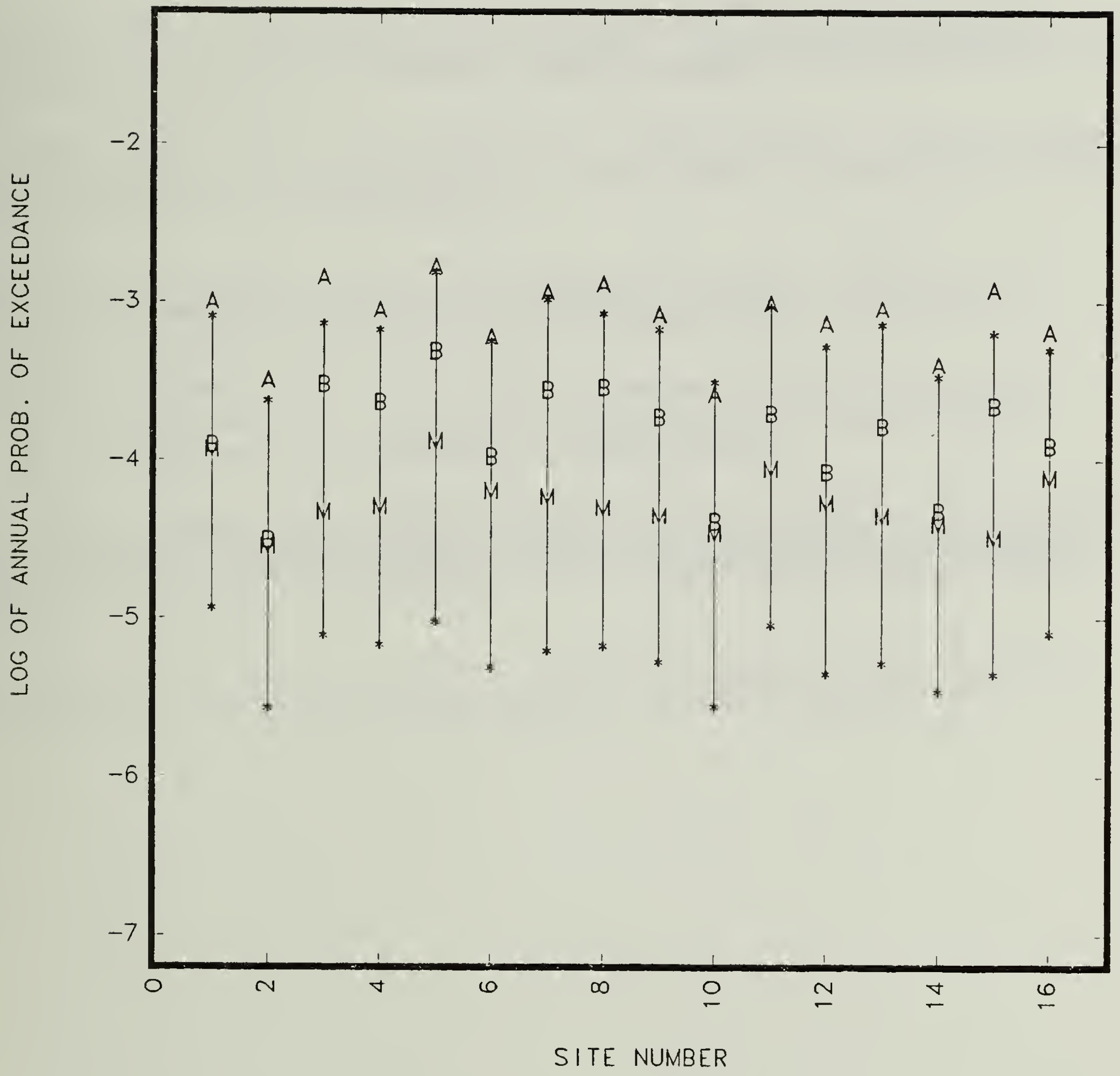


Figure 3.4.8 Median (M) probability of exceedance of 0.2g, best estimate (B), arithmetic mean (A), 15th and 85th percentiles (*) for the 16 sites of Batch 3.

Appendix A

References

Algermissen, S.T., Perkins, D.M., Thenhaus, P.C., Hangen, S.L., and Bender, B.L.k (1982), Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States, USGS, open file report 821033.

Bernreuter, D.L. and Minichino, C. (1983), Seismic Hazard Analysis Overview and Executive Summary, NUREG/CR-1582, Vol. 1 (UCRL-53030).

Bernreuter, D.L., Savy, J.B., and Mensing, R.W. (1987), Seismic Hazard Characterization of the Eastern United States: Comparative Evaluation of the LLNL and EPRI Studies, U.S. NRC Report NUREG/CR-4885.

Bernreuter, D.L., Savy, J.B., Mensing, R.W., and Chung, D.H. (1984), Seismic Hazard Characterization of the Eastern United States: Methodology and Interim Results for Ten Sites, NUREG/CR-3756.

Bernreuter, D.L., Savy, J.B., Mensing, R.W., Chen, J.C., and Davis, B.C., Seismic Hazard Characterization of the Eastern United States, Volume 1: Methodology and Results for Ten Sites, UCID-20421, Vols. 1 and 2.

Chung, D.H. and Bernreuter, D.L., (1981), "Regional Relationships Among Earthquake Magnitude Scales," Reviews of Geophysics and Space Physics, Vol. 19, 649-663, see also NUREG/CR-1457 (UCRL-52745).

EPRI (1985), Seismic Hazard Methodology for Nuclear Facilities in the Eastern United States: Preliminary Seismic Hazard Test Computations for Parametric Analysis and Comparative Evaluations, EPRI Research Project Number P101-2g (Draft).

EPRI (1986) (Electric Power Research Institute), Seismic Hazard Methodology for the Central and Eastern United States, 9 Volumes, EPRI-NP-4726.

Appendix B

Maps of the Seismic Zonation for Each of the 11 S-Experts

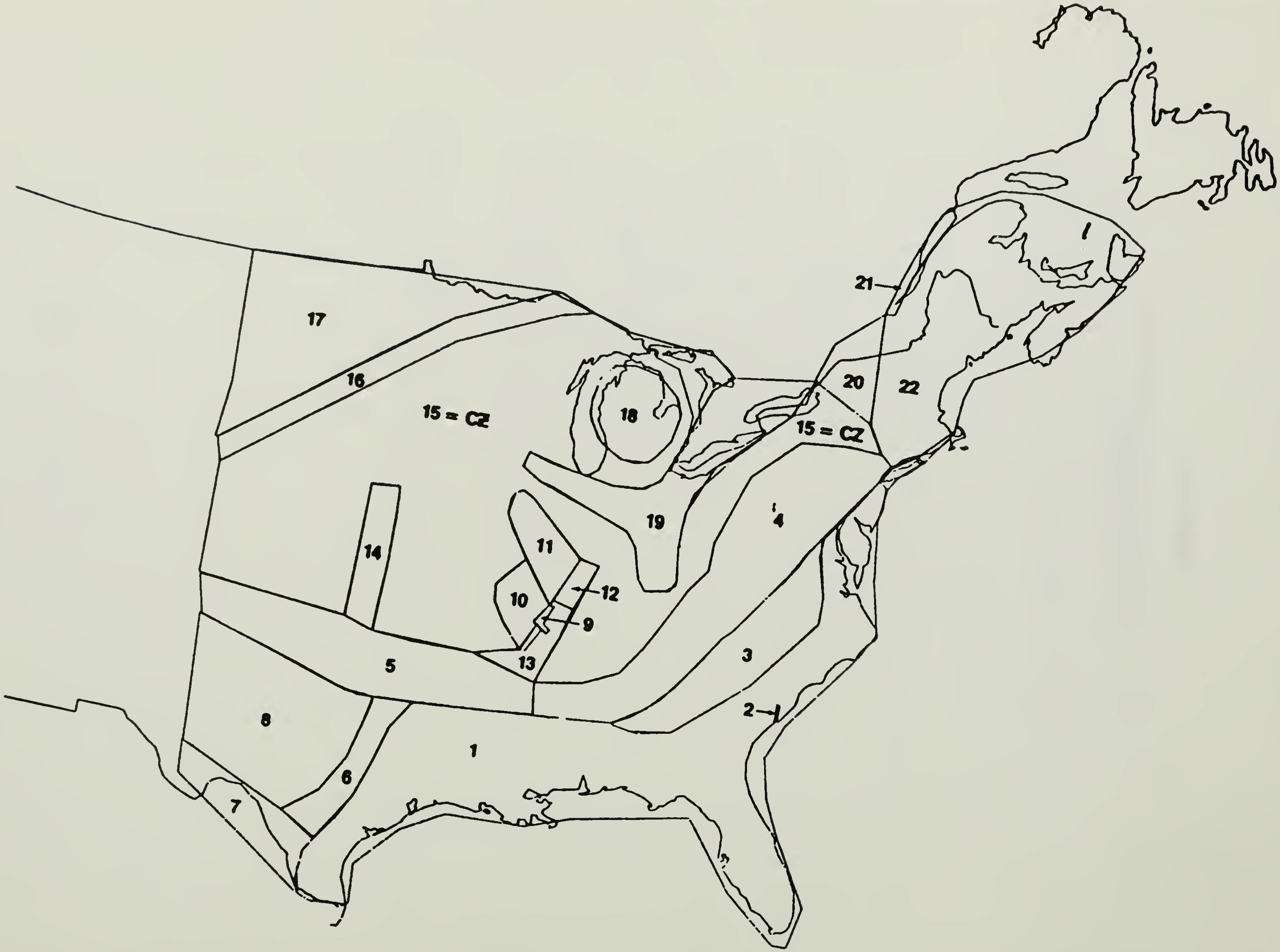


Figure B1.1 Seismic zonation base map for Expert 1.

Figure B1.2 Map of alternative seismic zonation to Expert 1's base map.

Figure B2.1 Seismic zonation base map for Expert 2.

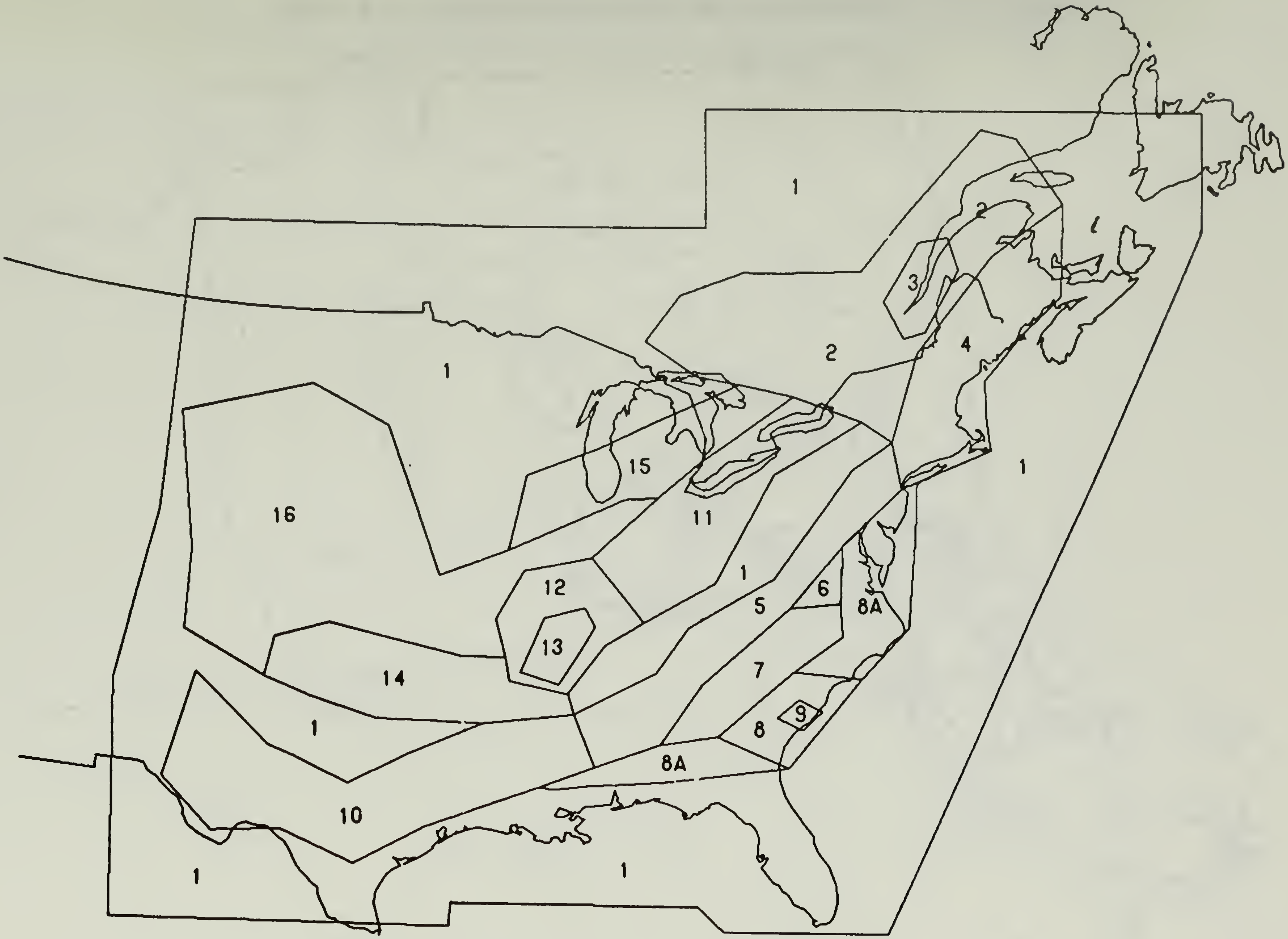


Figure B3.1 Seismic zonation base map for Expert 3.

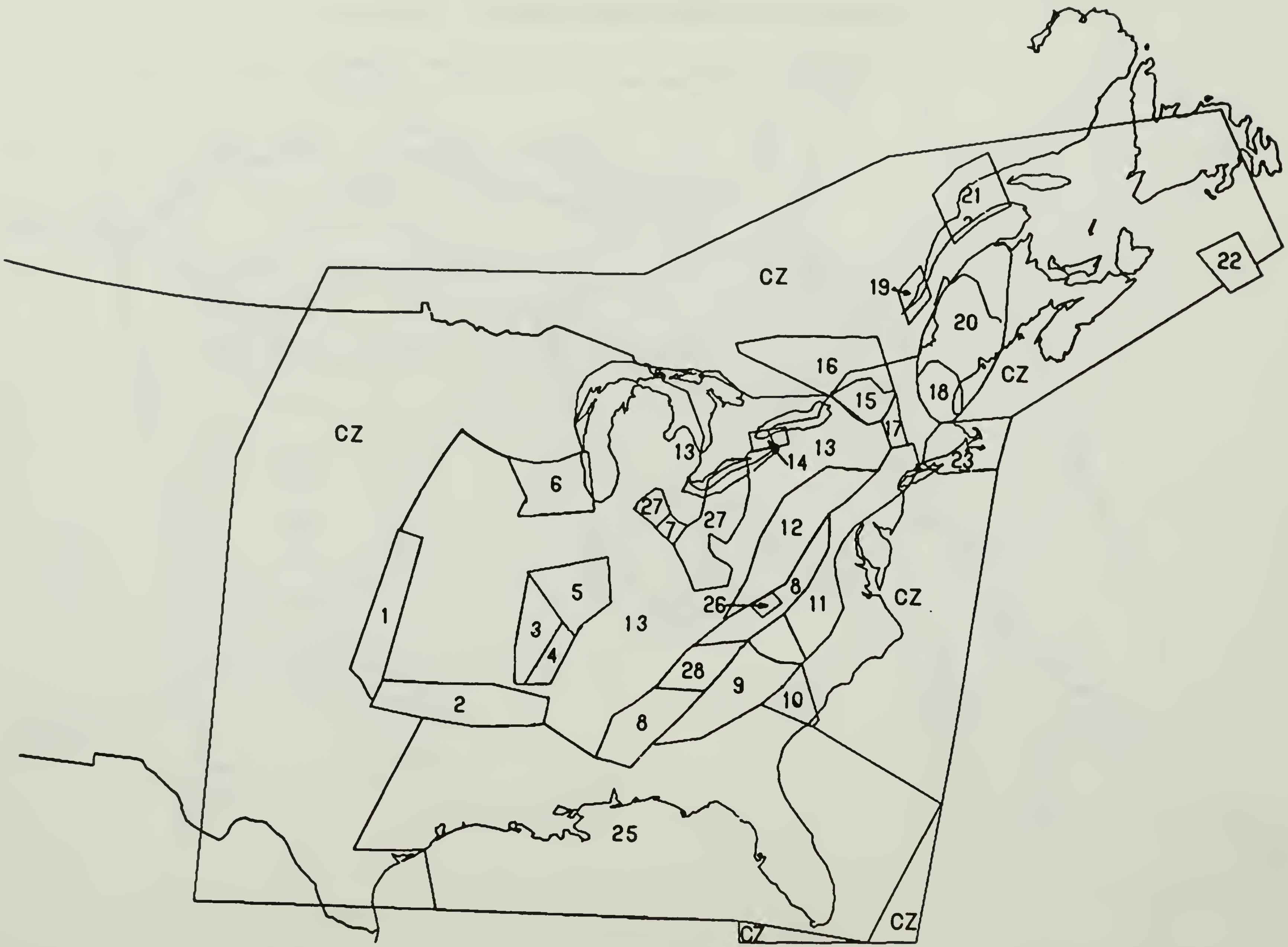


Figure B4.1 Seismic zonation base map for Expert 4.

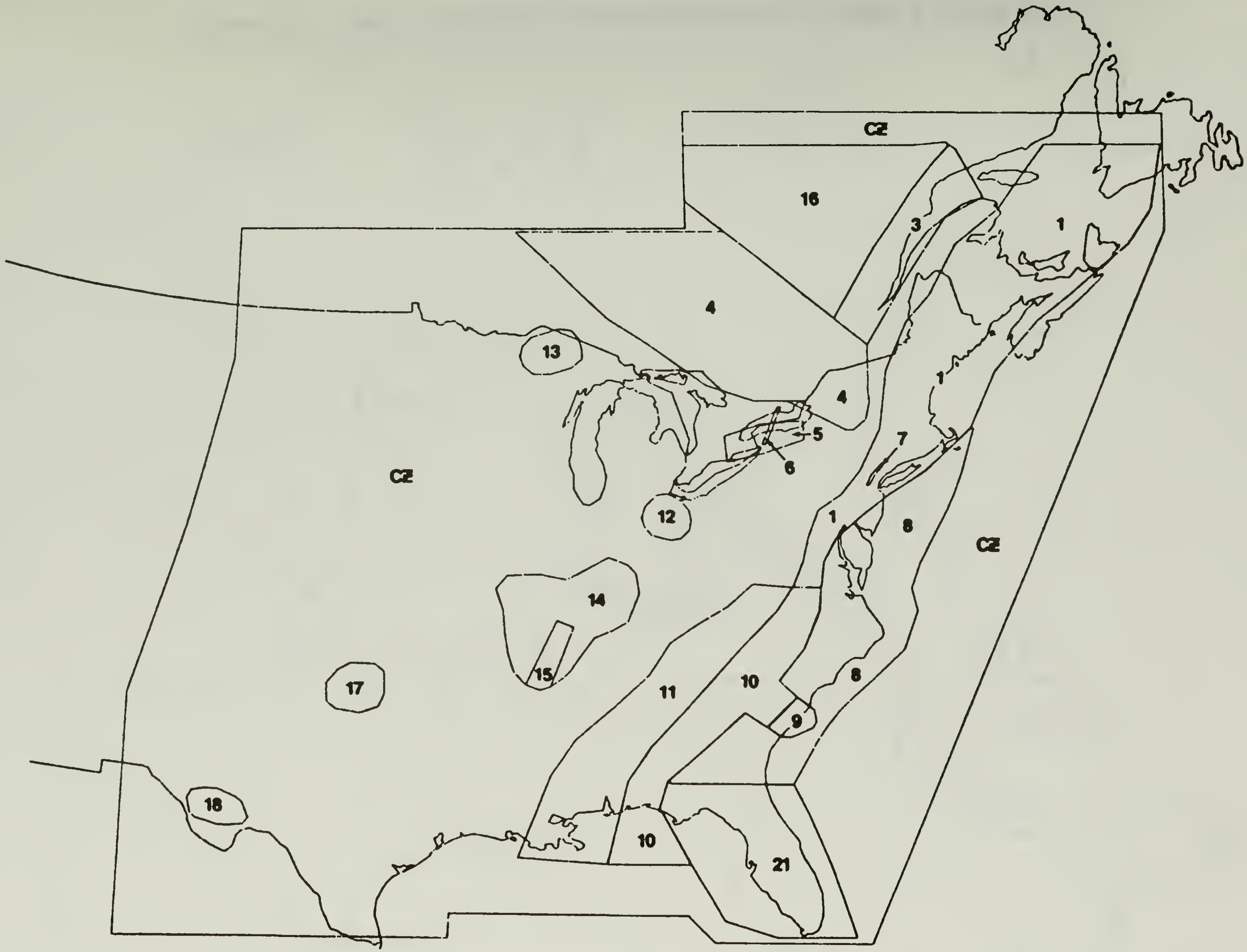


Figure B5.1 Seismic zonation base map for Expert 5

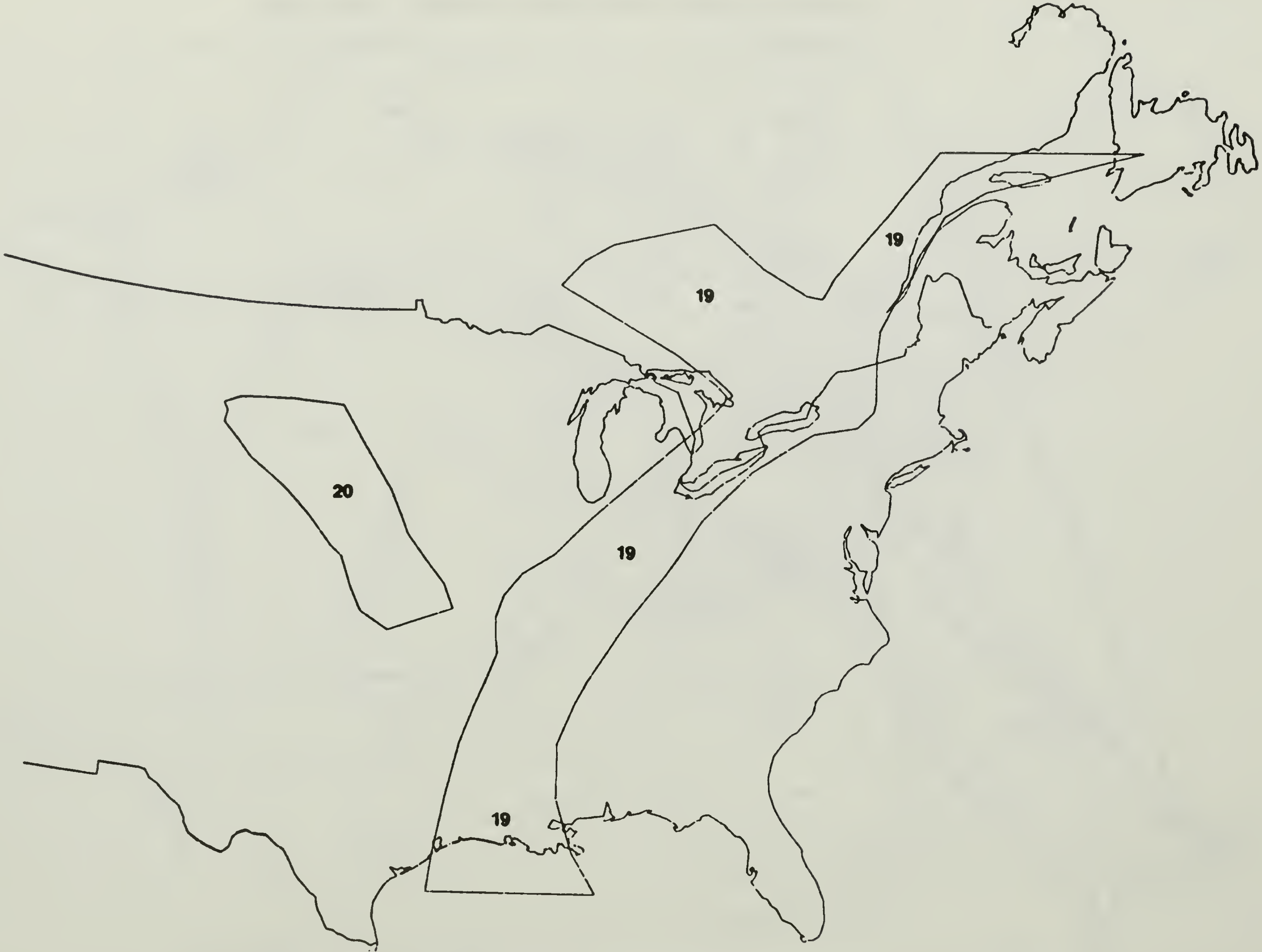


Figure B5.2 Map of alternative seismic zonations to Expert 5's base map.

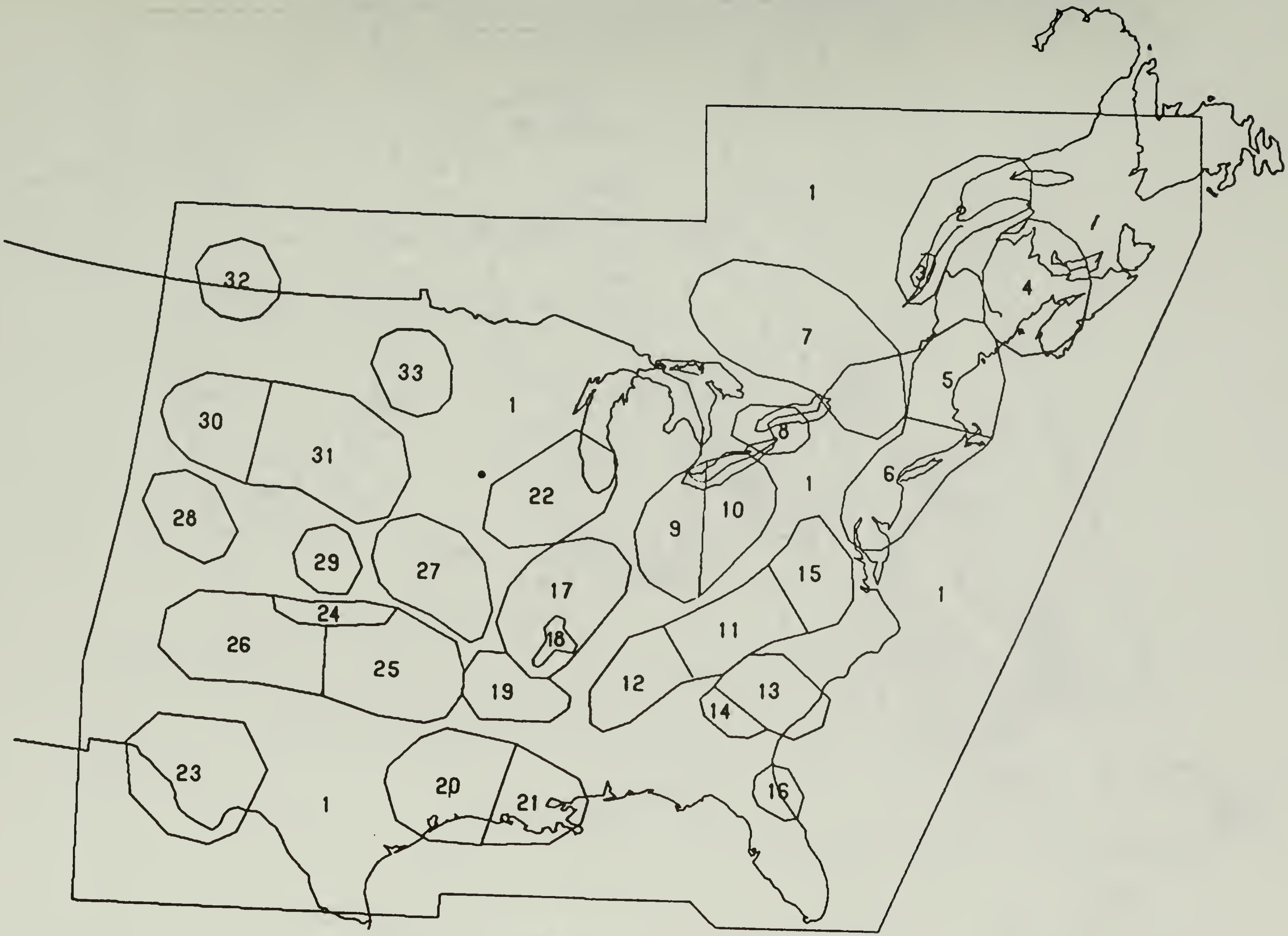


Figure B6.1 Seismic zonation base map for Expert 6

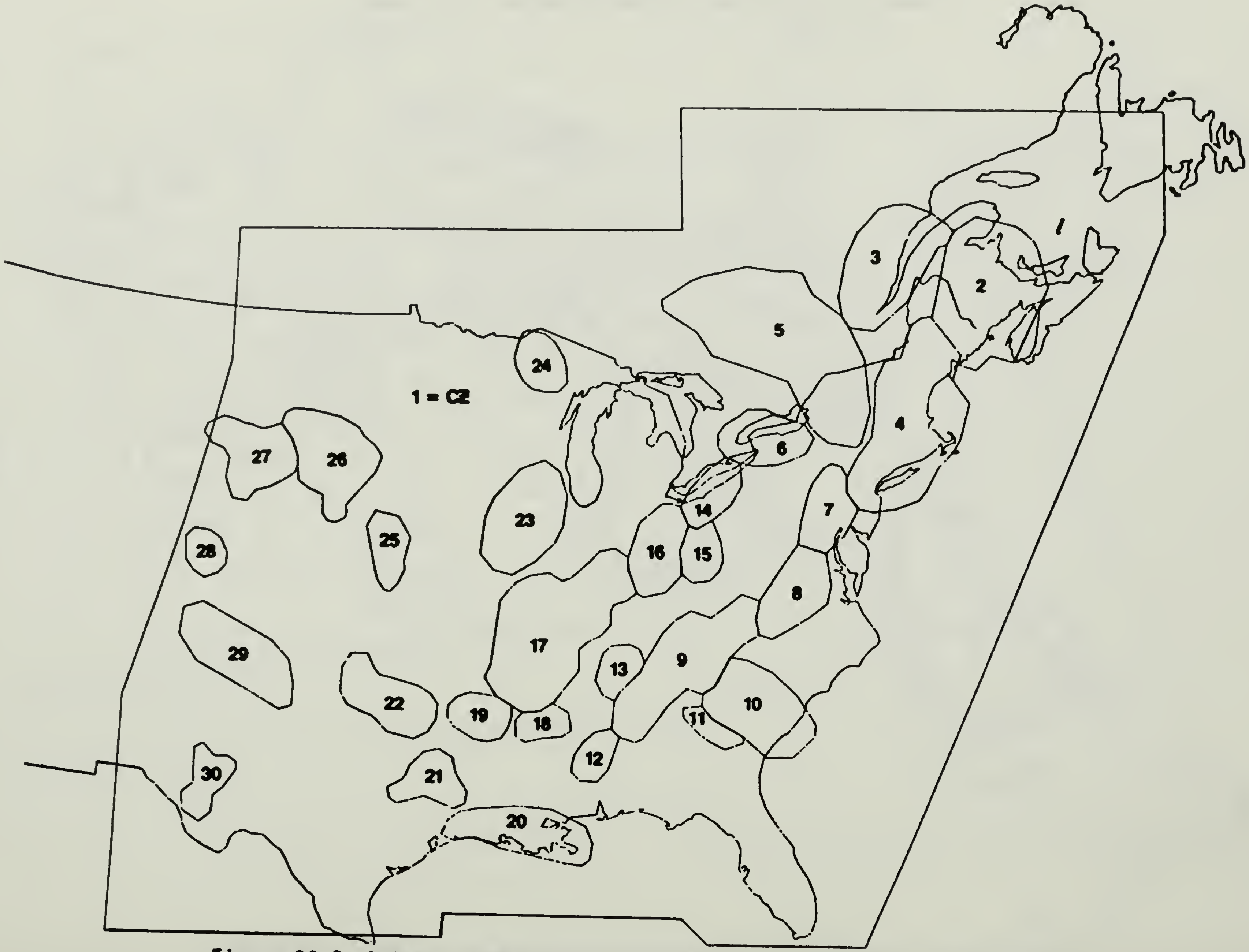


Figure B6.2 Seismic zonation map alternative 1 to Expert 6's base map.

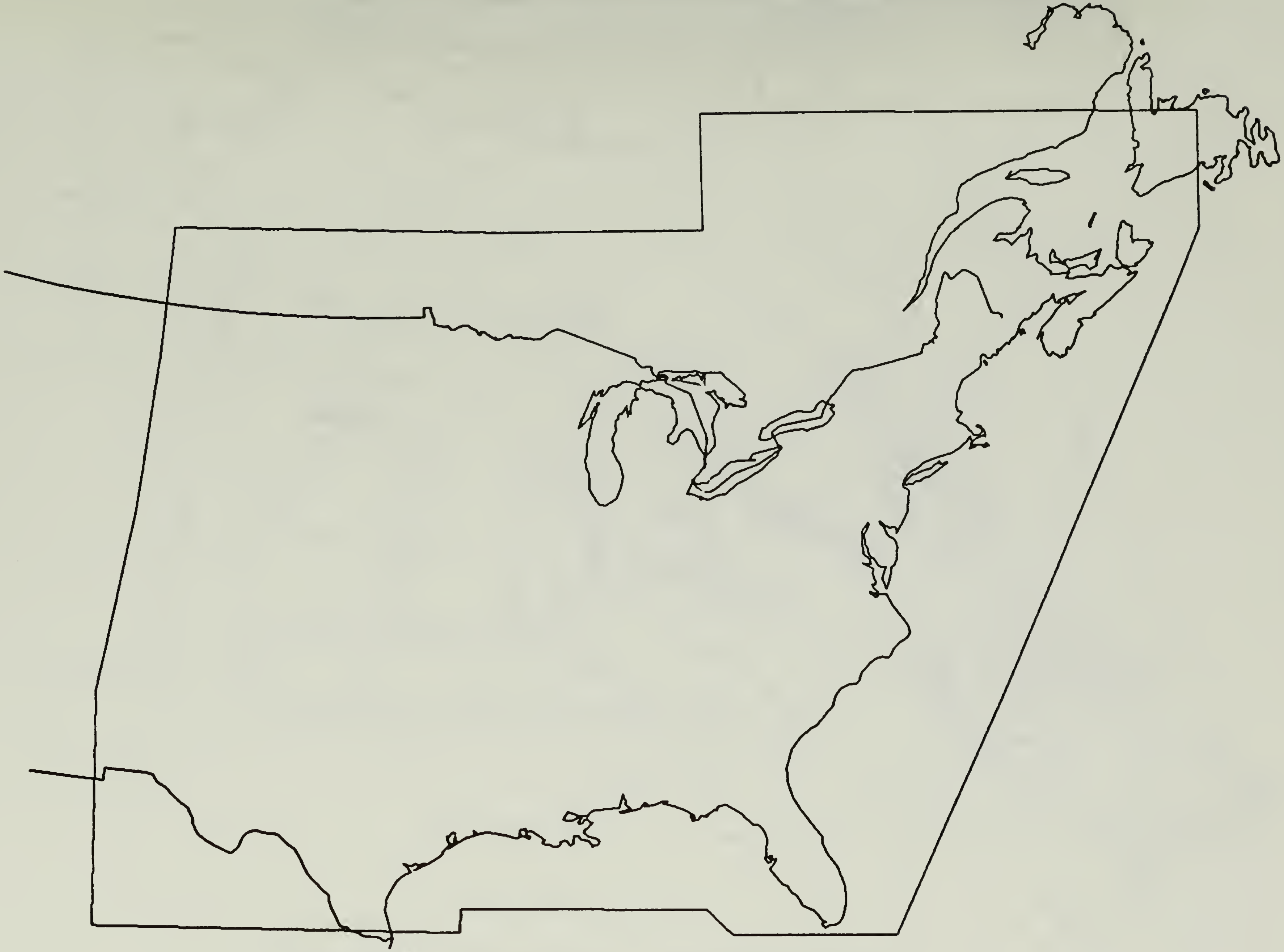


Figure B6.3 Seismic zonation map alternative 2 to Expert 6's base map.

Figure 7.1 Seismic zonation base map for Expert 7.

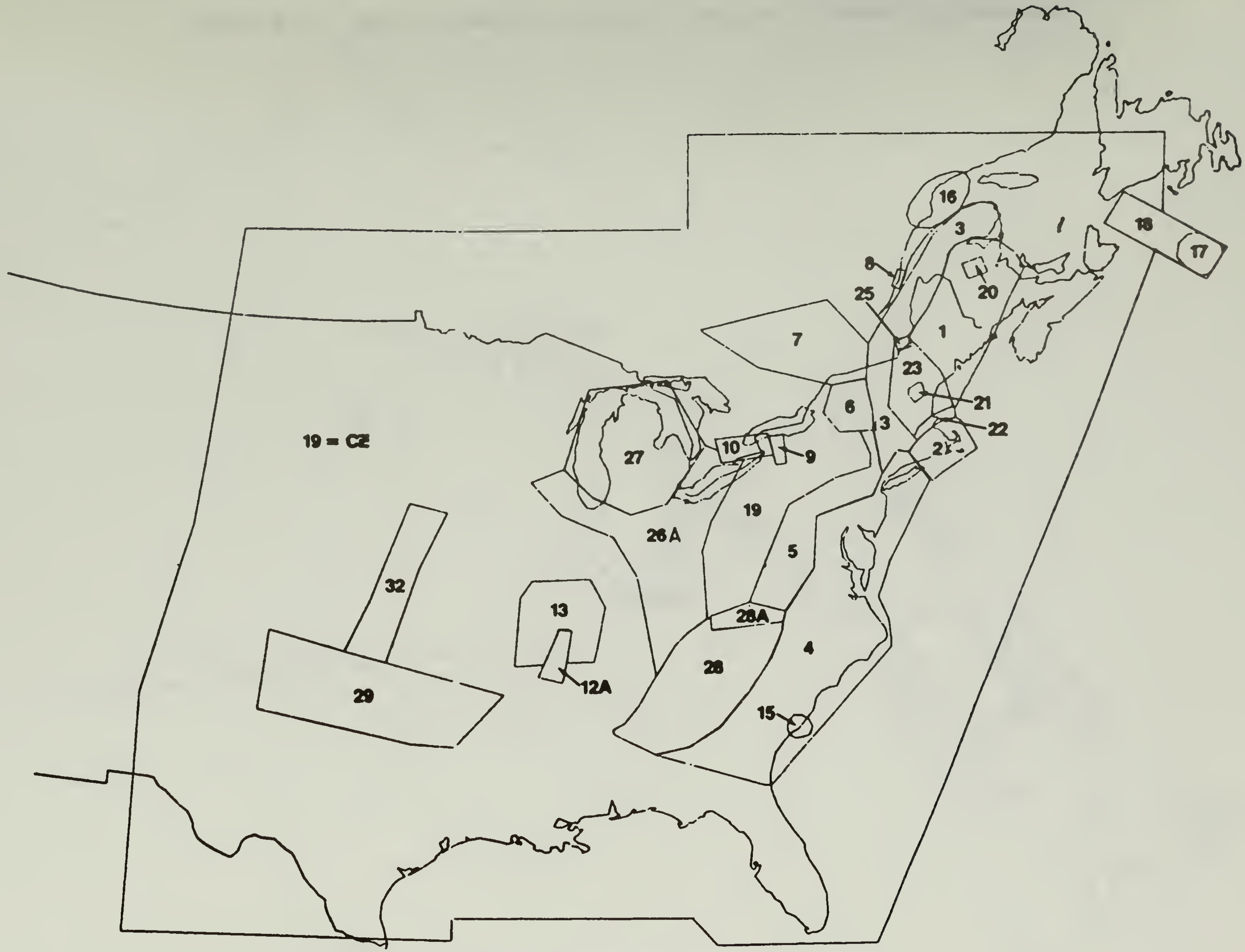


Figure B10.1 Seismic zonation base map for Expert 10.

Figure B10.2 Map of alternative seismic zonations to Expert 10's base map.

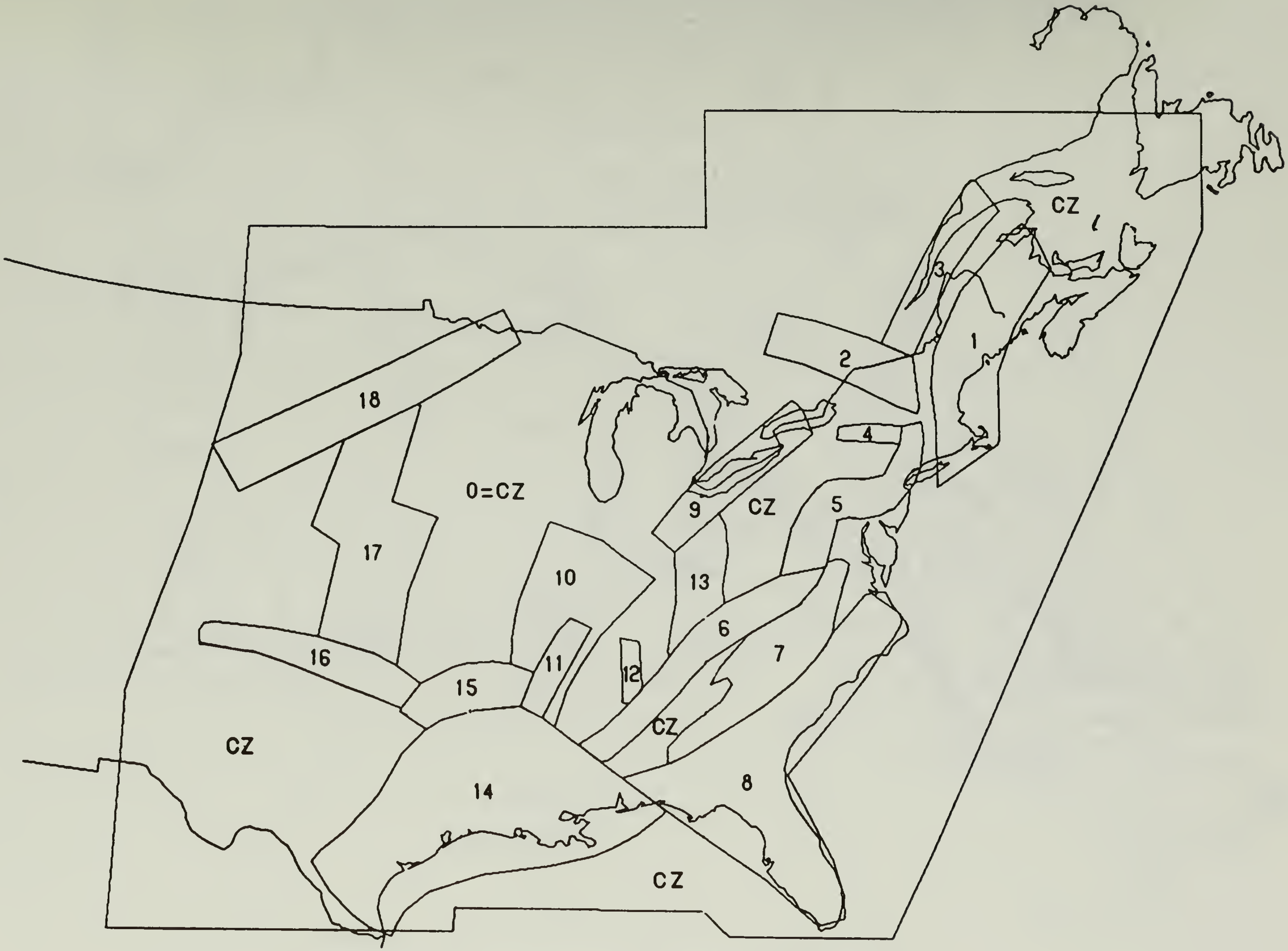


Figure B11.1 Seismic zonation base map for Expert 11.

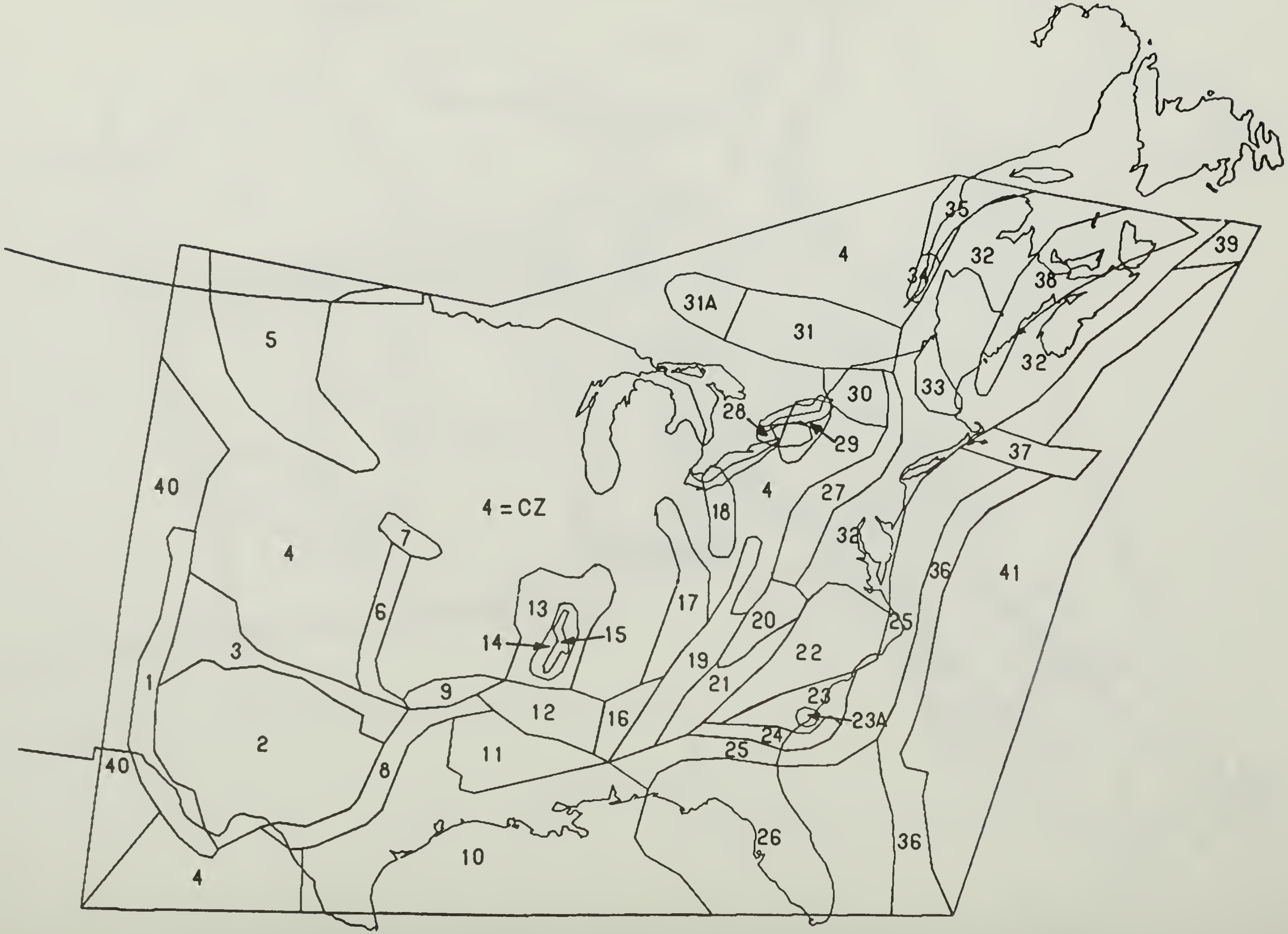


Figure B12.1 Seismic zonation base map for Expert 12.

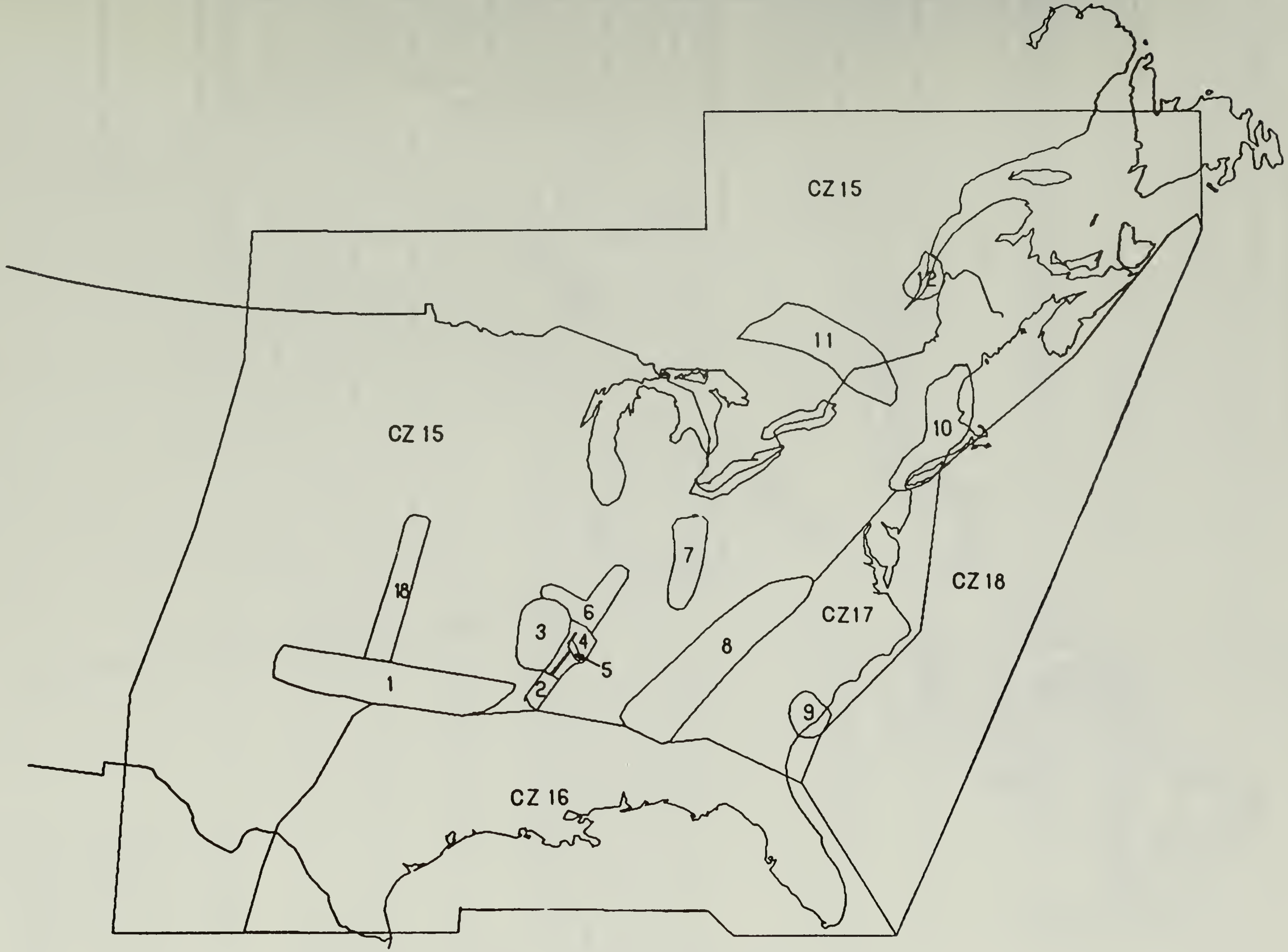


Figure B13.1 Seismic zonation base map for Expert 13.

Figure B13.2 Map of alternative seismic zonations to Expert 13's base map.

NRC FORM 335
(2-84)
NRCM 1102,
3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

SEE INSTRUCTIONS ON THE REVERSE

1. REPORT NUMBER (Assigned by TIDC, add Vol. No., if any)
NUREG/CR-5250
UCID-21517
Vol. 4

2. TITLE AND SUBTITLE
Seismic Hazard Characterization of 69 Nuclear Plant Sites
East of the Rocky Mountains
Results and Discussion for the Batch 3 Sites

3. LEAVE BLANK

4. DATE REPORT COMPLETED
MONTH November
YEAR 1988

5. AUTHOR(S)
D.L. Bernreuter, J.B. Savy, R.W. Mensing, J.C. Chen

6. DATE REPORT ISSUED
MONTH January
YEAR 1989

7. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Lawrence Livermore National Laboratory
P.O. Box 808, L-197
Livermore, California 94550

8. PROJECT/TASK/WORK UNIT NUMBER

9. FIN OR GRANT NUMBER
A0448

10. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Division of Engineering and System Technology
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

11a. TYPE OF REPORT
Technical

b. PERIOD COVERED (Inclusive dates)
October 1986-October 1988

12. SUPPLEMENTARY NOTES

13. ABSTRACT (200 words or less)

The EUS Seismic Hazard Characterization Project (SHC) is the outgrowth of an earlier study performed as part of the U.S. Nuclear Regulatory Commission's (NRC) Systematic Evaluation Program (SEP). The objectives of the SHC were: (1) to develop a seismic hazard characterization methodology for the region east of the Rocky Mountains (EUS), and (2) the application of the methodology to 69 site locations, some of them with several local soil conditions. The method developed uses expert opinions to obtain the input to the analyses. An important aspect of the elicitation of the expert opinion process was the holding of two feedback meetings with all the experts in order to finalize the methodology and the input data bases. The hazard estimates are reported in terms of peak ground acceleration (PGA) and 5% damping velocity response spectra (PSV).

A total of eight volumes make up this report which contains a thorough description of the methodology, the expert opinion's elicitation process, the input data base as well as a discussion, comparison and summary volume (Volume VI).

Consistent with previous analyses, this study finds that there are large uncertainties associated with the estimates of seismic hazard in the EUS, and it identifies the ground motion modeling as the prime contributor to those uncertainties.

The data bases and software are made available to the NRC and to the public uses through the National Energy Software Center (Argonne, Illinois).

14. DOCUMENT ANALYSIS - a. KEYWORDS/DESCRIPTORS
Seismic hazard, Eastern U.S., ground motion

b. IDENTIFIERS/OPEN-ENDED TERMS

15. AVAILABILITY STATEMENT
Unlimited

16. SECURITY CLASSIFICATION
(This page)
Unclassified
(This report)
Unclassified

17. NUMBER OF PAGES

18. PRICE

☆U.S. GOVERNMENT PRINTING OFFICE:1989-241-590:80328

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

SPECIAL FOURTH-CLASS RATE
POSTAGE & FEES PAID
USNRC

PERMIT No. G-67